

A

PRACTICAL TREATISE

ON DRAINING

BOGS AND SWAMPY GROUNDS, &c.

PRACICAL TREATISE

ON DRAWING

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PRACTICAL TREATISE
ON DRAINING
BOGS AND SWAMPY GROUNDS,

ILLUSTRATED BY
FIGURES;

WITH

CURSORY REMARKS UPON THE ORIGINALITY OF
MR. ELKINGTON'S MODE OF DRAINING.

TO WHICH ARE ADDED,

Directions for making a New Kind of Strong, Cheap, and Durable Fence, for Rich Lands; for Erecting, at little Expence, Mill-Dams, or Weirs upon Rivers, that shall be alike Firm and Durable; for effectually Guarding against Encroachments by the Sea upon the Land, and for gradually raising Drowned Fens, into Sound Grass-Lands.

AS ALSO,

DISQUISITIONS CONCERNING THE DIFFERENT BREEDS OF
SHEEP, AND OTHER DOMESTIC ANIMALS;

BEING

The principal Additions that have been made to the Fourth Edition of
ESSAYS relating to AGRICULTURE and RURAL AFFAIRS;
published separately, for the Accommodation of the Purchasers of the
former Editions of this Work.

BY

JAMES ANDERSON, LL.D. F.R.SS. &c. &c.

MEO SUM PAUPER IN AERE.

L O N D O N:

PRINTED FOR G. G. AND J. ROBINSON,
PATERNOSTER-ROW.

1797.

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ADVERTISEMENT.

The Author returns his best acknowledgements to those gentlemen who have obligingly offered to come forward with attestations of the success they have had, in following the directions given in former editions of this Work; but hopes, they will permit him to decline their obliging offer on the present occasion. He has no anxiety on this head; and is perfectly satisfied to leave his Treatise, as formerly, to the unbiassed judgment of an impartial Public, which he is conscious can never fail, ultimately, to decide with the most impartial justice.



INTRODUCTION.

THE principal part of the following Essay was first published in the year 1755; exactly as it now appears, (verbal corrections excepted) and had passed through three editions before the year 1795, when the President of the Board of Agriculture brought forward a motion in parliament, to obtain a premium of 1000*l.* to be given to one Mr. Joseph Elkington, for *discoveries* said to be made by him in the art of draining land. This naturally called the attention of the author to a subject, on which he had formerly written himself; and from the particular enquiries he made, he found reason to be satisfied, that the only particular in which Mr. Elkington's mode of draining differed from that practised in general throughout Britain, consisted in what he called, *tapping* for springs, a mode of draining which had been practised by the author more than thirty years before, and which had been particularly
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described and illustrated by figures in the first edition of these Essays. On this occasion, without any intention either to frustrate Mr. Elkington of his premium, or to claim any gratuity to himself, the author thought it expedient, politely by letter, to inform Sir John Sinclair of the mistake he had inadvertently fallen into, in ascribing that practice, as *an original invention, exclusively* to Mr. Elkington, and producing a quotation from this Essay, as a decisive proof that it was not a new thing. Sir John Sinclair, without advertg to those facts, chose afterwards to state, in two separate publications, in the most decisive manner, his opinion of the undoubted right that Mr. Elkington had to claim this invention *exclusively* as his own. This drew from the author a second letter to Sir John, in which the justice of that decision is controverted, and in which the author calls upon the Board of Agriculture to publish an account of Mr. Elkington's mode of draining, that the public may be enabled to judge impartially in this case. These two letters are here subjoined for the purpose

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pose of more clearly elucidating this subject.

TO SIR JOHN SINCLAIR, BART.

PRESIDENT OF THE BOARD OF
AGRICULTURE.

LETTER FIRST.

SIR,

*Cotfield, near Edinburgh,
30th June, 1795.*

I USE the freedom to trouble you at present, on the subject of draining, adopted by Mr. Elkington, not with a view to detract from the merits of that gentleman, nor to find fault with the remuneration you have obtained for him, but merely to set you right in regard to a matter of fact concerning me, which might easily escape your notice.

I presume, Sir, you thought it evident, from the statement made by Mr. Elkington, that the mode of draining ground, which has been so successfully practised of late, by that gentleman, was an invention peculiarly his own. That this is not the

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case,

case, admits of evidence, which, I hope, you will allow to be satisfactory. It is now twenty years since I published a book, called *Essays relating to Agriculture and Rural Affairs*. If you will take the trouble of turning to the second Essay of that work, which is *On Draining Bogs and swampy Ground*, you will there find the method of draining by means of *tapping*, which has been adopted by Mr. Elkington, fully explained, and the principles upon which it may be practised, clearly developed, by the aid of illustrative figures, discriminating plainly the cases in which that mode of practice would be improper.

I do not understand that Mr. Elkington practised this method of draining before the publication of that work (anno 1775) neither do I mean to assert that he adopted the practice from the directions there given. I readily admit that the principle is so simple, and so obvious to every considerate mind, that it would certainly be nothing extraordinary, if he, by his own reflections alone, should have discovered it, as well as I did. There is only one particular

particular in his mode that I myself had not practised before that Essay was published, viz. the making the tapping by means of *a boring instrument*; but even this I have particularly described, as you will find in the following words, at page 181 (*Third Edition, Vol. I*) of the foresaid Essays. After describing the mode of tapping I had adopted, by sinking small pits, and explaining the cases in which it may be successfully practised, it is added, “I have often imagined that the expence of digging these pits might be saved, *by boring a hole through this solid stratum of clay, with a wimble (an auger) made on purpose*; but as I have never experienced this, I cannot say whether it would answer the desired end exactly.”—Neither can I *now* say, whether Mr. Elkington grounded his practice on this hint or not; but I may safely say, if he did not, he might have done it: And as I could not have borrowed it from him, if there be any merit in the *discovery*, I have assuredly a just title to claim it.

I wish not to throw out any insinuation to the prejudice of Mr. Elkington, who,

by a proper degree of management on his part, has great merit in having turned the attention of the nation towards a mode of draining, which, if the principles upon which it is grounded, are fully understood, and properly applied, will be found to be equally cheap and efficacious; as I myself, from an experience of it for more than thirty years, can safely assert. But it is a mistake, to think it can be universally applied. There are many cases in which it can be of no use, and, therefore, it were vain to attempt it; as I have fully demonstrated in the Treatise referred to.

Whether Mr. Elkington did actually discover this mode of draining of himself, or adopted it from the very plain directions given in that Treatise, is of little consequence to the Public. In either case, he has alike the merit of having introduced it into practice in the southern parts of this Island: for the simple fact that he has been supposed to be the first inventor of it, is the clearest proof that this part of my Treatise, *by how many soever it may have been read,* has been allowed

lowed to remain, in a great measure, a dead letter, even till the present hour.

As my intention in publishing that Essay, doubtless, was to benefit the public, I owe, perhaps, thanks to Mr. Elkington, for having thus forwarded that design. It is not impossible that the time may not be far distant, when I shall be laid under a similar obligation to some other person, for bringing into practice, *as a new invention*, the mode of embanking rivers, which is described in the Essays referred to, with a similar degree of clearness; and which, when reduced into practice, will be an improvement equally cheap and efficacious with the above. An obligation of this sort was conferred upon me, some years ago, without my knowledge of it at the time, by a Mr. Brodie, I think the name is, when he brought into notice, what he called, the *Patent Bath Stove*; the principle upon which that stove is constructed, having been explained, and clearly illustrated by means of a plate in a Treatise of mine “On Smoky Chimneys,” that was first published in the year 1769; but this particular was little adverted to for

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several years, till Mr. Brodie, by a *little proper management*, brought it into notice†. My ideas, freely communicated to the public, have been a source of emolument or of honour to others also—my own reward has been the satisfaction of having done what I know to be right, and the *honour* of being indirectly flattered by compliments that were publicly appropriated to others.

Wishing you success in your laudable undertakings, which, if properly supported, cannot fail to be attended with effects highly beneficial to the nation, I have the honour to be, with due respect,

Sir,

Your most humble servant,

JAMES ANDERSON.

† It is generally believed that Mr. Brodie has realized a hundred thousand pounds by this contrivance.

LETTER

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LETTER SECOND.

SIR,

*Cotfield, near Edinburgh,
10th January, 1796.*

SINCE I had the honour of addressing you in public on the subject of draining land, I have learnt that a controversy has been carried on in the Newspapers to some length, upon the same subject, by various persons. Who these persons are I know not; and with the particular object that each party has in view, I am in a great measure unacquainted. I never saw one of these publications (except two, which accidentally fell into my hands in September last, when I passed through London). The present letter, therefore, must be considered as having no connection with, or reference to these publications; and if any thing shall here occur that shall tend either to corroborate or oppose any of these writings, it must be considered as merely accidental.

Since my own letter, above alluded to, was written, I have seen two publications by the President of the Board of Agriculture, in which the draining of land has been mentioned. The first is an Address to
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the Board of Agriculture, dated 14th July, 1795, in which it is taken notice of in these words: 'The Board has succeeded
' in its first application [i.e. to Parliament for a reward on account of *discoveries* advantageous to Agriculture] in behalf of a
' very deserving individual, Mr. Joseph Elkington, *who has carried the art of draining*
' *to a perfection hitherto unknown.*' The second is an Address to the Board of Agriculture, on the cultivation and improvement of the waste lands of *Great Britain*, by the President, printed 23d December, 1795, in these words: 'A considerable
' proportion of the wastes of Great Britain
' consists of lands of a wet and boggy nature, which it has been yet supposed was
' the most difficult to improve and cultivate.
' Fortunately, however, *discoveries* have been
' made in the art of draining such bogs,
' by Mr. Joseph Elkington, a farmer, in the
' county of Warwick, as renders the improvement of swampy land a matter of
' much less difficulty or expence than formerly.' My friends think that in both these passages there is manifestly a *marked* determination to set aside my claim
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to any share in the discovery of that mode of draining, and a studied care to avoid my name in any way, lest it might imply some sort of derogation from the merit of Mr. Elkington; and they farther think, that after the public claim I have already made to that discovery, it would argue little less than a consciousness of the injustice of my claim, should I suffer such a public affront to pass unnoticed. As some of Sir John Sinclair's best friends with whom I have spoken upon the subject concur in the same opinion, I find myself called upon to urge a farther explanation on that head; which is one of the principal objects of the present Address.

The question at issue may be reduced to a very narrow point, which is this: The practice of Mr. Elkington is, in its principle, either the same with that which was practised by me, more than thirty years ago, and the principle of it developed and clearly illustrated by figures, in Essays relating to Agriculture and Rural affairs, which were published in the year 1775; or it is not. If it be the same, then, doubtless, Mr. Elkington can have no just title
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to be held out to public view, *exclusively*, as the discoverer of this practice; for I presume, he will not allege that at the time of the discovery, I had ever heard of him or of his practice. Indeed, I never did hear of either, till his name was first mentioned in some of the publications of the Board of Agriculture. On the contrary, as it is certain that my discovery was published more than twenty years ago, and that Mr. Elkington has never till this hour published his, but has been going on from imperfect beginnings, gradually improving as he went on, it is not so clear that he may not have borrowed some hints to direct his practice, either directly from my treatise, which has been pretty generally read in Lancashire, or from the conversation of some persons who had read it. From these considerations, if the principle be the same, it will be difficult for the President of the Board of Agriculture, to clear himself from the imputation of a marked partiality in the passages above quoted; especially after my having pointed out to him, in my former letter, the passages in
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my Essays, that directed the same method of practice so long ago, as has been already specified. If, on the other hand, the practice followed by Mr. Elkington differs in principle from that which I had so long ago explained; in that case, the President of the Board of Agriculture may be with reason accused of injustice to the public, by having delayed so long to explain the principle of that useful discovery; for, as the public have already paid for the discovery, they have a right to demand that it should be made more generally known for the benefit of the whole community, in the same manner as Mr. Forsyth's receipt for recovering decayed trees was published, on receiving his premium. I therefore, in the name of the public, demand of you, Sir, who have taken the lead in this transaction, to publish this secret; that all the world may be enabled to know it, and to avail themselves of it, if they incline, without being obliged to have recourse to Mr. Elkington himself, who in this instance, like the venders of quack medicines, carefully conceals his secret, that he may be enabled to pro-

fit by the credulity of the public : And shall the President of the Board of Agriculture, demean himself so far, as to give countenance to such transactions!!!—I will not suppose, that such can be the case. Yet appearances are against you. —Inadvertence may have led you to adopt a language that is fairly susceptible of that interpretation; and you cannot take too early an opportunity of doing it away.

It will be the easiest thing imaginable for Sir John Sinclair to clear himself from this charge, and settle the matter,—simply by publishing the principles on which Mr. Elkington's method of draining is founded. This can be attended with little trouble :—For as Sir John must fully understand the principle himself, (otherwise it would be an insult to suppose he could have adopted a language so strong and decisive as he has done)—he can find little difficulty in explaining it, as a supplement to one of those publications that are every day issuing from the press, at the expence of the Board of Agriculture.

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Such a publication is likewise necessary on Mr. Elkington's account, if he means to free himself from the imputation of quackery; which idea, the manner in which he has been introduced to public notice, by the Board of Agriculture, has a strong tendency to countenance. This ought to be done away, if he wishes to gain that respectability of character, to which superior talents should naturally entitle him. With such men, *candour* is ever a leading characteristic feature; for, however far concealment and deception may lead to emolument in certain cases, it never can be accounted honourable. Now, if Mr. Elkington is sensible, that he understands the principles upon which his practice is grounded, so completely as to be able to explain it in such a satisfactory manner, as to set at defiance the critiques of philosophical investigators, he can have no objections to publish it. He has received a price for it; and not only honour calls for it, but *justice* requires it at his hand. If neither the President, nor any other member of the Board of Agriculture, nor Mr. Elkington himself, shall, after being

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thus

thus called upon, publish the secret that he has sold, the public will be disposed to believe that Mr. Elkington cannot do it, and that he has availed himself of the influence of some great man, to impose upon the President and the Board of Agriculture, who have thus, in their turn, been induced to lend their aid to enable him to dispose of his nostrum to the best advantage. From these considerations, it alike behoves the President, the Board of Agriculture, and Mr. Elkington himself, to lose no time in publishing his secret. Among other good effects that will result from this measure, it will totally preclude all farther altercation respecting the merit of this discovery between him and myself, or others.

Till such publication appears, it may not be improper in me to observe, that another body of men, who have had good opportunities of information, have thought proper to adopt a conduct, respecting this particular, very different from that of the President of the Board of Agriculture. The gentlemen who compose the Society of Agriculture, at Altringham, near Manchester,

chester, in the county of Lancaster, having determined to encourage the draining of land by means of tapping, judged that a respect for their character required them, in this case, to act with the strictest impartiality: And thinking it would be of use to those who were to attempt it, to know the principle on which success depended, as well as the mechanical practice of the art, the Society offered a premium to those who drained the greatest quantity of land, 'according to the practice followed by Mr. Elkington, on the principles explained by Dr. Anderson, in a book called Essays relating to Agriculture and Rural Affairs.'

The following is Mr. Elkington's own account of the way in which he was first led into the train of discovering his mode of draining by means of tapping, as it was told to me by a gentleman of great veracity, who had it from Mr. Elkington himself; and it appears to be so natural, as fully convinces me that it is strictly the truth. Mr. Elkington's father having died about the year 1763, left him in possession of a small farm of wet four land.

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He found that no good could be made of it without previous draining. He accordingly set to work to drain it in the usual way; but after having laid out as much money as his narrow funds could afford, he had the mortification to find that no benefit had resulted from his labour; which tended very much to discourage him. While he was in a state of despondency on this account, he, by accident, dug a little deeper than usual in one of his drains, and found, to his great surprise, that a copious spring of water burst forth from the hole, which continued to flow with a plentiful stream for a very long period of time. He dug deeper, in several other places, with the same effect, though the streams were less copious than the first. In consequence of these openings, he had the satisfaction to perceive, that his fields gradually became drier and drier, till they at last were perfectly freed by it from all the superfluous moisture. And not only were his own fields thus drained, but the contiguous land, for a considerable distance all round, was made drier also by the operation. This circumstance led him
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to suspect, that in other cases, where the surface appearance of wet land was somewhat similar to his own, they might be drained by making openings resembling those above named. Success attended his operations in many cases; and he gradually went on in his practice, correcting his first errors by experience, and improving upon it till the present time.

From this account, it would seem that the discovery was, as to him, merely accidental; nor does it appear, from the above, that he had any clear idea of the manner in which the draining is thus effected, or the principles on which it depends, so as to be able to distinguish *à priori*, those cases in which that mode of draining could be of no use, from those where it must of necessity prove efficacious.

As to myself, the discovery of that mode of draining was made in the following manner: I had a field of wet land that lay very flat, but so surrounded by ditches, that no surface water could come to it from higher ground any where, and possessing at the same time such a level as to prevent any water from necessarily stagnating upon

it. The field was so wet, that in many places it was a mere hobbling bog, over which a man could scarcely pass during the driest weather in summer. This was a very unprofitable as well as disgusting object; and, in the beginning of the year 1764, I set about seriously to have it drained. On considering the circumstances of the case with attention, I soon perceived that as no *surface* water could come upon it from the higher ground; and as the rain that fell upon the field itself was suffered freely to run off, the water that drowned it must rise up from *below*. But as the weight of the atmosphere acted on this field as well as on those around, the water could not be made to ascend, as in a pump, by means of suction: it must, then, be forced to take that direction in consequence of some powerful pressure from below ground, acting so strongly as to overcome its natural gravity. This pressure, it was evident, could only be in consequence of the water flowing from higher ground, *under the surface*, through a stratum of pervious matter, being pent in near the bottom,

bottom, by a stratum of clay placed above it, and thus forced to rise to a higher level, than the low ground, in this kind of subterraneous canal, so as, by the natural power of gravity, to be squeezed forcibly through small fissures in the superior stratum of clay. If so, it would necessarily follow, that should a hole be dug through the superincumbent stratum of clay, so as to reach the bed of the reservoir, the water would be allowed to issue freely through that opening, and to run off the ground by its natural level; and thus would the accumulated water, which occasioned the pressure, be gradually discharged, after which, it could no longer be forced up through the small fissures in the clay; and, of course, the wetness, which had arisen solely from that cause, must be gradually removed. On this reasoning, which seemed perfectly conclusive, and which was confirmed by observing that the subsoil of that field was every where a very stiff clay, mixed with small stones, the dry weather was no sooner set in, than I put a man to dig a pit as near to the

edge of the swaggle as he could approach, ordering him to penetrate directly downwards, making the pit no larger than was sufficient to allow him to work, and to proceed without interruption, until he should perceive that, on making his strokes, it should sound as if it were somewhat hollow below. On observing this, he was desired immediately to desist, until he called me, and received farther orders. The labourer accordingly fell to work; but he found the ground so hard, that, in the course of two days, he had only penetrated to the depth of about five feet. During that time, I frequently visited the work, to examine appearances. Nothing remarkable occurred, save that little peering springs often were discovered, through which the water issued; but the quantity of water that came from them was not such as to interrupt the work. On the morning of the third day, about breakfast time, the labourer called on me, and said, that as his stroke gave a *douf sound*, (that was his phrase) he had called me, according to my desire. I went immediately with him to the place, and having
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made him go down into the pit, I desired him to show me in what manner he could come out of it. He then pointed out to me, a kind of steps he had made into the clay on one side; and having lent him my hand to assist him, I found he could get out very quickly. I then ordered him to take a kind of sharp-pointed iron crow, with a cross handle and foot to it, which he had found a very useful tool in loosening the clay, and give a stroke of that with all his force upon the bottom, which he did.—On this, to his great surprise, the tool penetrated a thin crust, and then fell down, from one to two feet, as in a vacuumity. Through the opening thus made, a strong jet of water rushed instantly with great impetuosity; but I, being aware of it, and at hand to assist the man in mounting, he got very quickly to the surface, and out of all danger, though not a little terrified at what had happened. The stream was at first so large, as might, I suppose, have filled a pipe of from six to twelve inches diameter; and rose, as a *jet d'eau*, to the height of six feet at least, above the surface of the ground. The labourer, who had no idea of such a phe-

nomenon, looked upon it with an overpowering astonishment, which would have furnished a fine subject for the painter. The stream continued to flow, and to rise above the surface of the ground for about a week; but gradually abated in height, till it arose not above the surface of the ground, and continued still to flow; but the quantity of water gradually diminished, till it at last settled into a perennial spring, which continues to run till the present day.

The consequence of this operation was, that during the course of the ensuing summer, the water gradually drained off from the boggy ground; the swaggle slowly acquired a firm surface, so as to admit of being ploughed at any season; and about twenty acres of ground were thereby drained, which, before that time, had been, in a great measure, useless for every agricultural purpose.

Ten years afterwards, being about to publish an Essay, containing directions for draining all the different kinds of wet grounds that occasionally prove detrimental to the farmer, I naturally specified this variety of wet ground among the others, and gave a plate
explanatory

explanatory of the cause of that phenomenon, as I had done of the others, in order that every person who chose it, might be enabled to distinguish the case, and apply the remedy himself, if he so inclined. The Essay has been now in the hands of the public above twenty years, and will speak for itself; so that more need not be said here on that head, farther than that all these facts could be *proved*, were it thought necessary to do so.

I may add, however, at present, when I find that a disposition is manifested, on some occasions, to withhold honour from those to whom honour is due, that though I did not think it proper in a work that professedly treated of agricultural concerns only, to specify all the useful corollaries that might be drawn from the physical appearance above explained; I may now, without any impropriety, barely mention, that from the application of this principle, many phenomena may be explained in a very satisfactory manner, which have been hitherto reckoned cases of great difficulty. Some of these, (particularly the case of a well that was sunk at Tilbury Fort, on the Thames, as narrated

rated in the Phil. Tran. Vol. in which an abundant spring of *fresh* water was found, at a great depth below the surface of the sea, after two springs of *salt* water had been passed through above it) I pointed out, in a letter I did myself the honour to write, several months ago, to Leigh Philips, Esq. of Manchester, who had been kind enough to say, that the essay referred to, was what he conceived to be a *complete system of draining*. This expression induced me to show him it could not be deemed *complete*; as several cases were omitted, which I then specified to him: among others, it was stated that deep lakes, surrounded by mountains of great height on all sides, may, on some occasions, be entirely drained, by *bor-ing*, or sinking shafts downwards, sometimes to a moderate depth: That also, wet-land may, on some occasions, be more easily drained, by opening an outlet for the water *beneath* the reservoir which occasions the wet, than by bringing it up to the surface. And that among mountains, it may frequently be much cheaper to carry off superfluous water from mines, by penetrating downwards, than by driving a horizontal level

level to the surface of the ground, which is in many cases attended with a ruinous expence. These corollaries are indeed so obvious, when the principle is once explained, that it must appear astonishing to any considerate mind they have not been made, and very generally applied in practical cases, long before the present period; and I here specify them, merely to direct the attention of men to an object from which much practical good may be derived, in a variety of cases, which it would be tiresome in me here to enumerate.

I have farther to add, on this head, that there is one variety of wet ground which had totally escaped my notice in that Essay, and which has not, that I know of, been treated by any writer on agriculture; though it is perhaps more universally hurtful to the farmer, than any other kind of wet land whatever. This I shall have occasion particularly to explain, in a treatise now in the press, on the improvement of waste lands.

From the facts that were stated to the committee of the Board of Agriculture, in favour of Mr. Elkington's mode of draining,

draining, as published in their *report*, dated June 5th, 1795, there seems to be reason to suspect, that Mr. Elkington himself, even at that period, was not fully aware of all the circumstances that were essential to the practice of draining ground, in the most economical manner, by means of tapping;—as the labour and expences incurred, in many of the cases there specified, seem to be much greater than that mode of draining, judiciously applied, could possibly have required. But as these cases are stated by gentlemen who did not themselves fully understand his method, they may possibly have been done with some degree of inaccuracy. When Mr. Elkington himself shall publish his own method, that doubt will be removed; and every individual will then be able to judge for himself as to this particular. If his practice be as good as it is said to be, it cannot be too soon or too generally made known. If it shall be defective in any respect, these defects cannot be too soon pointed out and rectified; which would probably not be long delayed after the publication required,

I shall

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I shall be sorry, if, in consequence of the precipitate conduct of Mr. Elkington's friends, I have been obliged, for the purpose of obtaining impartial justice, to say any thing here that may tend to prove, in the smallest degree, detrimental to that gentleman. I look upon him as a very worthy member of society; and I believe him to be an honest man. I have not a doubt but his practice has already been of much national utility, and will be of still more, the wider it is diffused; even although it should not be carried on in the most perfect manner of which it will be found to be ultimately susceptible: and I can assure that gentleman, with much sincerity, that there is not a man in the land, not the President of the Board of Agriculture himself, nor his still more powerful patron, who will rejoice more in his prosperity than myself, or who would more gladly lend his aid to the extending his practice as wide, and the rendering it as perfect, as possible. It is, perhaps, unfortunate, when a plain man finds himself forced to come forward in the genteel circle,—especially where such person
may,

may, by the ill-judging partiality of ignorant friends, be induced, from the hope of benefiting his family, to acquiesce in statements that he himself would never perhaps, have made, even though he be backed by those who have the most powerful influence: For it is not in this nation, that influence can altogether suppress the voice of reason, or ward off entirely the severity of reprimand, when the influence of supposed power provokes a scrutinising enquiry.

I have now, Sir, done with the business of Mr. Elkington, but am sorry, that, in justice to myself, I am not yet at liberty to put an end to this, I fear, ungracious epistle.

It appears to me very strange that I should have occasion, at one time, to complain of having been ill used in *two* respects, by Sir John Sinclair, as I am not conscious of ever having merited any thing of that sort at his hand, *but much the reverse*. It unluckily happens to be so, however, at present. The trespass, too, is of such a kind as to require that notice should be taken of it in the public manner

I, now

I now do, in order that I may remove, in part, at least, the injury that, by his improper conduct, must have been done to my character. I shall briefly state the facts, for the justness of which statement I appeal to yourself.

Immediately on receiving a letter from the President of the Board of Agriculture, in February last, requesting that I would favour the Board with any information I could give respecting the culture and uses of Potatoes; I sat down, and in great haste, put upon paper such observations as occurred to me at the moment. These observations, without revision or corrections, were instantly forwarded to the Board, under cover, addressed to the President, and were accompanied by a letter, stating that I had lost no time in complying with the wishes of the Board respecting the subject of Potatoes, and that the papers which accompanied that letter, contained what appeared necessary for me to say on that head. But, I added, that these remarks were intended solely for the use of the Members of the Board itself, and “were not intended to be *published*.”

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This I forbade in the most positive manner; and even requested that the Board would be so kind as not to mention my name, in any publication they might think proper to make on that subject; desiring that the papers might be returned to me, after the Members of the Board had satisfied themselves with regard to them. So anxious was I that this requisition should not be forgotten, that I mentioned it no less than three times, in as many different letters I had afterwards occasion to write to Sir John Sinclair; and as the franks had been reduced in weight before the last letter was written, I desired him, with a view to avoid the trouble of addressing so many covers as it would then require, to send the MS. to my son in London, who would take care to get it forwarded to me. After all this, the reader will judge of my surprise, when I read these words in a letter from Sir John: ‘The Board has at length finished its publication, on the subject of Potatoes; *and as you have been a contributor to it*, you are entitled to a copy of it.’ In what manner I had become a contributor to that work, I could not well conceive;

conceive ; for I did not then imagine, that ever he could think of publishing what I had so positively forbidden : but as some observations of mine on Potatoes had been printed in other publications, I thought something might have been extracted from these works, to which this passage might allude. I took the earliest opportunity that offered, to consult that work for my own satisfaction. My astonishment at seeing the observations printed entire, with all their faults, and others superadded, and thus forced upon the public notice, “ unanointed, unanelled ;” and the indignation I felt at this unexpected insult, may be easier conceived than expressed. I call it an insult, because I conceive that no one acting in the character of a gentleman, can have a right to publish the writings of another, even without his consent, far less, if contrary to his express injunctions, clearly announced, and repeatedly enforced. You, Sir John, have it in your power, by publishing my letter, to correct, me if I misrepresent the fact. If I have stated it justly, it is incumbent upon you to make such an apology, as one gen-

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tleman ought to give, and another to receive.

What adds *injury* to the *insult*, on the present occasion, is, that from the whole tenor of the writing, it was obviously intended for private information only, and not at all for the public use; and if you had taken the trouble to read, with an ordinary degree of attention, the first sentence only, you could not have failed to perceive it. You need scarcely be told it may be extremely proper to express in a particular way, what was obviously calculated for the private perusal of a few gentlemen only, who were about to judge of matters that were not within the sphere of their observation; though it would be exceedingly preposterous to make use of the same expressions, when intended to be laid before the best-informed professional men in the kingdom. The observations which, in the one case, would only be calculated to induce that cautious circumspection which men of professional knowledge, in any line, are in some measure required to use, when called upon to assist those

those of less experience, whose situation in life incidentally may bring them to decide in matters respecting that profession; but, in the other case, as being addressed to professional men, many of whom may be supposed, to be equally well informed as the writer himself, could be considered as little better than an insult, and would indicate an overweening presumption in the writer, that could only excite disgust and contempt. Such, in fact, is precisely the case in the present instance; and the words of the introductory paragraph to that Essay, if they were supposed to be intended for publication, can only be calculated to make an impression on the mind of every reader, that is very little in favour of the writer; and what I conceive to be extremely different from what my own character, if not obscured under such an humiliating disguise, ought naturally to produce. I feel, at least, that if any other person had written such a paragraph, intending it to be published, as this has been, I should have despised him as an impudent coxcomb, whom it would be a merit to humble. Sir John Sinclair, is

as capable as any man of judging of the irresistible effects of such impressions on the public mind; nor would there have been any thing extraordinary in it, if he had, on receiving such a paragraph for publication, from a man with whom he was in habits of intimacy, requested him to reconsider it, to see how far he thought it proper for the public eye, on the supposition that it had escaped his notice through inadvertency. But to publish it in that imperfect state, though contrary to the express orders of the writer, repeatedly enforced, without giving him even a hint of such an intention, was using a freedom, which no man, whatever his situation in life may be, has a right to take with another. The law has provided a punishment for him who injures his neighbour's good name. The injury may be as great when it is done in this way as any other, though it has, perhaps, hitherto escaped the notice of legislators. With those who shall read this letter, perhaps, *a part* of the injury may be done away; but Sir John ought to consider that thousands may have seen the publication al-
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luded to, who may never have an opportunity of reading this, and that the writer must continue to be despised by them till the end of time.

Besides the circumstance above alluded to, there are other blameable particulars, originating from the publication of that performance, by the Board of Agriculture, that must affect the character of the writer ; for so little attention has been paid to the printing, that from the incorrectness of the press, he must, in some cases, appear to write in a manner altogether unintelligibly, and, in others, he is made to speak perfect nonsense*. I will not say that these things were intended : But is it fit that one person should suffer a material injury, through the carelessness of another ; especially when that is produc-

* EXAMPLES. I had said, ‘ But now *that* fresh kinds are obtained from *seeds*,’ which is printed, ‘ But now *the* fresh kinds are obtained from *reds*.’ I had said, ‘ Nor are those kinds that send their bulbs deep in the ground, so *desirable* as those that rise upwards,’ which is printed, ‘ so *durable* as those that rise upwards.’ I had said, that in a rich mellow soil, ‘ the roots would be able to strike with ease, and *find* abundant nourishment ;’ it is printed, ‘ and *send* abundant nourishment.’

ed, not in the ordinary course of business, but is occasioned entirely by the culpable forwardness of that person ?

I am happy at being now come nearly to the close of a letter, the writing of which has been to me a very unpleasing task ; for I mean not to bring forward any other complaints against you, at this time ; and hope I never shall be forced to do so, at any future period. I do not take pleasure in finding fault ; and in few cases could it prove more irksome to me than the present. Anxious as I have been, through the whole course of my life, to see the prosperity of this country augmented, by promoting the peaceful exertions of rural industry, and thus preserving the morals of the people untainted, the only sure basis of national welfare ; I cannot but feel a sensible regret, at any degradation of the character of the man who has taken the lead, for the present, in that laudable undertaking. Undoubtedly, nothing tends so much to exalt a man's character, and to give him superior weight on all occasions among his equals, as that unbiaſſed integrity, which, rising
above

above those partialities and prejudices that are inseparable from little minds, presses steadily forward in its course, without wavering, however assailed by the tempting lures that may be held out to it, on either hand, by the artful and designing. It was this that raised Aristides, the Athenian, to that exalted pre-eminence which suppressed even competition itself, and gave him singly the power of adjusting the claims of rival states. Such a character commands respect, even where talents are rather defective; and will make errors themselves be overlooked by most men: but where this divine attribute is wanting, the most brilliant talents display their lustre in vain; and even the most useful pursuits, by such men, are frustrated. I have been hurt, Sir John, at the obvious partiality of your conduct towards myself, and the apparent design, unfairly, to lessen my character with the public. Should a similar weakness, to use the mildest expression, be perceived in regard to others, the influence of the Board of Agriculture must soon be lost with the public. It will only be then viewed as one of

those tiny institutions, that are calculated to soothe the vanity, or to augment the political influence of certain individuals for the time. I most anxiously wish that this may never be the case; and shall only add, that if any thing I have here said, shall, by inducing a little more circumspection, where the reputation or the interest of others may be affected by any casual inattention on his part, tend to render the character of Sir John Sinclair, still more respectable than it has hitherto been, it will add to the pleasure and happiness of

Sir,

Your very sincere well-wisher,
JAMES ANDERSON.

Whether it was in consequence of the demand above made, or from any other motive, the author cannot say; but in the news-paper called the *Sun*, for June 3, 1796, the following account of Mr. El-kington's mode of draining was published. As soon as he heard of it, the author took the earliest opportunity of reading it, which
he

he had no sooner done, than he repented him of having, in some measure, pledged himself in that letter, to make some remarks upon it. Writing, where one finds little to commend, is but a very unpleasing task. On the present occasion, it became peculiarly so, because the honest man, against whom would seem to apply, any censure that should be made, appears himself to be abused.—No wonder, then, if the task was undertaken with reluctance, and as long delayed as possible. When about to publish the present edition of these Essays, however (Feb. 1797) the author thought it incumbent on him, after what had passed, to take some notice of this publication; and with that view, he read it over with greater care than he had done before, which enabled him to perceive, that he could happily get rid of the task; for, unless it be in a very few particulars indeed, he finds, that from the most painful attention he could bestow upon it, he has scarcely been able to collect a single consistent idea from the perusal of that performance.—At the first cursory reading, he believed, indeed, that he should be
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able to make something of it; but afterwards he found, that in proportion as the passages were examined with care, these nascent ideas evanished. He now, therefore, is forced candidly to acknowledge, that he cannot collect, *from this paper*, any thing that can decisively shew, whether Mr. Elkington's mode of draining be the same, or different from his own. That the reader may judge for himself, however, in this case, and that the present Treatise may be made as complete as possible on this subject in itself, that paper (which is not very long) is printed entire, with as strict an attention to accuracy as he could bestow. It is, however, so far fortunate for Mr. Elkington, that it does not appear to be written by him. Indeed, it bears internal evidence sufficient to prove, that it never could have been written by him, or by any one who had actually *practised* draining.

MR. ELKINGTON'S MODE OF DRAINING.

EXTRACTS *from the* MINUTES *of* PROCEEDINGS *of the* BOARD OF AGRICULTURE, *respecting* Mr. ELKINGTON'S *Mode of Draining Land.*

“ It is a circumstance hardly to be credited, that the principles on which the draining of land depends, should have remained so long unascertained, considering the great private benefit, and the many public advantages, which must necessarily be derived from carrying so important an art to perfection.

“ The following narrative will explain the circumstances, that led to so valuable a discovery ; which, however immaterial in themselves, it was thought right to preserve, as a proof, among many others, how trifling incidents may produce very important consequences :

“ About 30 years ago (anno 1763-4) Mr. JOSEPH ELKINGTON, then 22 years of age, took a farm, called Princethorp, containing nearly 200 acres, situated in the parish

rish of Stretton upon Dunsmore, in the county of Warwick.—The parish had been lately inclosed by act of parliament, but the farm he possessed consisted chiefly of poor quality, not being worth more than six shillings per acre. It was extremely wet; and finding that it rotted his sheep, he determined, if possible, to drain it.—The field in which he began was of a wet, gravelly nature, and full of springs. In order to drain it, he dug a trench, from four to five feet in depth; but after proceeding with it for about 100 yards, he found that no water entered the trench, and consequently that he had not hit upon the spring which occasioned the mischief. A thought accidentally struck him, that it might be of use to know what kind of strata lay under the trench, whether hard or soft, and how near it lay to the rock. He got an iron-crow or bar for that purpose, about 18 inches in diameter (such as the Warwickshire farmers commonly make use of for making holes, into which their stakes for fixing hurdles are put). This crow he forced down about three feet into the earth. Upon
taking

taking it out, to his astonishment, a great quantity of water burst out, and ran down the trench.—This naturally led Mr. Elkington to think of applying an auger, as an instrument better adapted for the purpose of boring. Upon trial, he soon found that to be the case; and by following the same plan, using the auger where necessary, he was at last enabled to drain all the wet parts of his farm*.

“ The

* This account of Mr. Elkington's discovery, differs in nothing materially from that which is stated in my letter; only it appears, that the precise date of this supposed discovery, seems to be carefully kept out of view. It is here said, that he *took his farm* (observe, it is *took* his farm, not that he *entered* to it, far less that he made his discovery in draining) in the year 1763-4. For aught that here appears to the contrary, he may have entered into the possession of his farm, in the year 1774: for I have known many leases of farms *taken ten or twelve*, some *twenty* years before the entry to them. But to put aside all appearance of cavilling, let us suppose that the ambiguous date of 1763-4, means that he *took* it in 1763, and entered to it 1764: I take particular notice of this circumstance here, because, in the answer Sir John Sinclair wrote to my first letter, printed above, after apologizing to me, for having obtained a premium for Mr. Elkington, instead of myself, he seemed to consider the priority of the date of Mr. Elkington's

“The advantages attending the draining of this farm, were very great indeed.

Elkington's discovery, as the ground on which he must determine. “I am to meet with him (says he) at Wooburn Abbey, on Monday next, when I shall have this circumstance fully investigated, and inform you of it.” The publication above, is the first intimation I had of it. Now, by what is here said, it could not be earlier than the year 1764; probably it must have been many years after—for it is said, the farm rotted his sheep, which he could not know, till he had been in possession of it at least one year. From the very next paragraph it appears, that he had not kept it one year only, but several years before he began to drain; for it is there said, “when he first got possession, he lost, *in the course of a few years*, above 800 sheep by the rot.” The original discovery, therefore, must have been made by him, not in the year 1764 or 1765, but several years, at least, posterior to these years. Whence comes it, that Sir John should now *studiously* speak with so little precision, to a point that he confessedly considered to be of a most primary importance. I, for my own part, consider it to be of no consequence who made the discovery, if discovery it must be called; for I doubt not, but it had been made by others long before either Mr. Elkington or myself was born:—but a man ought to be consistent with himself. Such disingenuous shifts, to disguise truth, excites contempt for the meanness of the person who adopts them, rather than resentment for the injury intended by them. Through every paragraph in this paper, the same disingenuous effort is clearly discoverable: Might it not be said, in this instance, “the spirit is willing, but the flesh is weak?”

When

When he first got into possession, he lost, in the course of a few years, above 800 sheep by the rot; whereas, since the farm was completely drained (one season alone excepted, when a field that had not been particularly attended to, rotted about a score) his flock has never been affected by that disease."

On the Principles of Mr. Elkington's Mode of Draining.

"WETNESS of land, in so far as it is connected with the present enquiry (for it is unnecessary, on this occasion, to take any wetness into consideration, if occasioned by the overflowing of the sea, or of lakes, or of running water) must either proceed from rain-water lying on the surface, or from springs issuing from below.

"No water will remain upon the surface, but upon clay, or where the substratum is clayey, for through the more porous soils it naturally subsides. Clay, however, being of a tenacious nature, water can
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neither pass through it from the surface to the bottom, nor from the bottom to the surface. In such land, therefore, there can be no springs, and the water that falls on the surface must remain upon it, unless there is a descent, and the water is carried down by surface-drains, or until it is exhaled by the air, or by the sun.

“ Where the surface does not consist entirely of retentive clay, but is porous above, though tenacious below ; the Essex or Hertfordshire mode of hollow-draining may be successfully practised.

“ The object of Mr. Elkington’s system, however, is, the draining of lands rendered wet by waters confined beneath the surface, and attempting to rise in the manner of springs. It is necessary, therefore, in the first place, to ascertain the nature of springs.

“ According to Mr. Elkington’s idea, springs originate from rain water, saved and collected by the hills and rising grounds ; which water subsides through particular strata, and runs either over or under such other strata as are impervious to water, according as they happen to lie,
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when the water comes into contact with them. He also supposes, that there must be great quantities of water preserved in the bowels of the earth, either in a few or in many reservoirs, according to the extent of which, springs are either temporary, (flowing only in wet seasons, and in general bursting out on the sides of hills) or perpetual, which are chiefly to be found at the bottom.—Where the quantity of water is great, and the orifice or channel small, the water must necessarily flow in equal abundance, at all seasons of the year.

“ Springs, he divides into two sorts:—Land-springs, which being supplied by a small quantity of ground (perhaps only a single vein of sand or gravel) must soon run dry; and bog-springs, which being supplied by a hill, or great tract of country, must necessarily be more regular and abundant.

“ In regard to the regularity of bog-springs, it is to be observed, that whatever may be the quantity of rain that falls upon a hill, and subsides through its porous soils, or through the fissures of the rocks, and then falls into reservoirs; yet the

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quantity of water that issues at the spring, in any given space of time, must depend upon the size of the orifice, at or near its mouth; and the velocity with which it flows, is according to its descent from a greater or lesser height.

“ There are only four substances through which springs naturally issue; namely, 1. Rock, whether consisting of stone or hard chalk; 2. Gravel; 3. Sand; and, 4. Marle.

“ When springs issue through clay, it can only be in consequence of the clay being perforated, and upon this circumstance, in a great measure, depends the success of Mr. Elkington's mode of draining; for the wetness of land, arising from subjacent water, is in general occasioned by this, that the water runs under a stratum of clay, until it comes either to rock with fissures in it, or to gravel, sand, or marle; it then rises, or endeavours to rise, to the surface, and in wet seasons overflows the land thus circumstanced. But if, by perforating the stratum of clay, you can intercept the water, and thus prevent its rising, or can give it an easier channel,
you

you may then conduct it in any manner that may be thought most advisable, and the land which lies above the bottom of the trench is drained.

“ The object of Mr. Elkington’s system, therefore, is that of draining land injured by subjacent waters, not by using palliatives, but by obtaining the command of the subterraneous waters themselves, and thus completely, and radically, cutting off the cause of the mischief. Where there is only one collection, or one principal vein, with several smaller ones, this may be done as effectually by one drain as by a thousand.

“ The different kinds of soils in which Mr. Elkington has principally worked, are, 1. Clay; 2. Sand; 3. Bogs, or Morasses.

“ In many parts of England, there are veins of sand, where the ground is of a clayey nature, and where the soil is commonly called clay, because that substance predominates. In such a soil it is very difficult to work, as it requires a number of trenches, because there is no general mass, but only partial collections of water.

The water is collected in beds of sand or gravel, which, perhaps, may have no communication with each other, being crossed and intercepted by beds of clay; and, consequently, as many trenches must be cut as may be necessary to extract the water from every bed of sand or gravel, each vein of which, if surrounded by beds of clay, becomes a separate reservoir of water; at the same time, there is no impracticability in draining land of that mixed description, though it requires more pains and attention. In this mixed sort of soil the ordinary modes may be successful.

“ It is also difficult to drain any field where sand predominates, as the water subsides through it. In land of that description, it is better that the drain should be open, and also very wide, that it may not easily fill up.

“ But the great object of Mr. Elkington's system is that of draining bogs; and it is in every point of view the most important; because, in the first place, immense tracts of valuable land, of a morassy nature, are lost to the community,
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from an idea, that it is impossible to drain them : and in the second place, because land of that nature and value, in proportion to its extent, can be drained at the smallest expence, and when they are drained, are, perhaps, the most valuable of any.

“ When a bog or morass is to be drained, the first object is, to ascertain the direction in which the trench should be dug. This is the most difficult part of the whole business, as it is hardly possible to explain it by words or writing, owing to the great variety of bogs, and the great diversity of countries in which they are situated.— No man can acquire this art completely without a great deal of practice. Such rules as Mr. Elkington has been able to furnish, are as follows :

“ 1. As the whole depends upon the nature of the bog to be drained, and the state of the adjacent country, as much knowledge as possible must be obtained respecting the strata in the neighbourhood, whether consisting of stone, gravel, sand, or marle, as the water must be lodged in one of these, and it is necessary to ascertain which.

“ 2. The trench must be directed so as to hit the bottom of the bed which occasions the mischief, and the particular spot where the main spring lies. One spring probably occasions the whole bog, which having no proper vent, forces the water through a number of small veins, even to a great distance, and makes the whole a swamp. By draining that main spring, the others follow of course.

“ 3. If there are various beds through which water issues, the stone is the one to be preferred for draining the whole, as the water is much more easily drawn through it, than through gravel, sand, or marle; consequently, by draining the spring there, the whole water which communicates therewith flows through it; water always preferring a straight or clear to a crooked channel. But in stone beds, the trench ought to be made from six to eight yards from the tail of the bed, or the place where the rock ends; because, in limestone, and in other rocks, the tail, as it is technically called, is harder than any other part of the rock, and there are few, if any, fissures in it; but by going a few yards

yards above, you get into a softer part of the bed, and the water is more accessible. The tail of these beds may often be found in a point or promontory, jutting out from the adjacent heights.

“ 4. The trench, in general, should be directed in a line with the bottom of the hill, because it makes the best separation between the Upland and the Meadow Inclosures, and the spring can best be intercepted. The trench, however, must be carried in the line of the spring, or near it; for if it diverges from it at any distance, all prospect of reaching the spring, by tapping it, or otherwise, is over, and the labour bestowed upon digging it, is probably lost.

“ 5. It is better to make a new trench than to tap the spring in any old brook or run of water, where that may be practicable; for though the spring, when once it bursts out, has force enough to throw up any stones, sand, &c. that may accidentally fall into it, yet brooks, in a flood, may bring down such immense quantities of sand, &c. as completely to overweigh and choak up the spring, and so much caution

is necessary to prevent any risk of such a circumstance, that when the trench crosses any runlet of water proceeding from a small brook, or from a collection of surface water, the trench is puddled, so as not to receive it, lest it should blow up, and destroy the works.

“Lastly, having fixed on the general line of direction, and marked out the trench, you are to begin at the bottom or lowest level, carrying your trench gradually up, the spirit-level in this part of the operation being your guide. The fall for the water need not be very considerable; a few inches in a hundred yards will be sufficient.

“In digging the trench, no tools but those of the most common sort are made use of, and common labourers can carry on the trench, under an experienced foreman or overseer. The auger, which must often be made use of for tapping the spring, may be from one and a half to two inches diameter, and is applied in the ordinary manner. If, in boring, a stone is met with, the auger must be taken off, and a chissel
or

or punch screwed on, to penetrate so hard a substance.

“ Sometimes the spring is cut off by the trench alone; but in many cases it lies greatly below the level of the trench, in which it is necessary to make use of the auger, for tapping the spring, as it is called. Mr. Elkington bored an auger-hole near Tamworth, thirty feet in depth, which threw water up equal to three hogheads in a minute, and completely drained all the neighbourhood.

“ To judge when to make use of the auger, is a difficult part of the business; and here it is to be observed, that if the water, from having a straight and clear channel, rises without difficulty through the hole made by the auger, it may draw off the spring above, and even drain all the neighbourhood, and you may proceed no farther. For natural springs often issue through narrow and crooked perforations, and, consequently, the water may prefer the easier though lower orifice. If it is certain that all the water in the spring flows through the hole made by the auger, you may there stop; if not, the trench
must

must be carried farther, and the auger again made use of.

“The trench being once made, and the spring cut off, either by tapping or otherwise, it is then necessary to determine whether the drain should be open or covered. If the drain can with propriety be made a fence at the same time, it had better be open, if not, it ought to be covered. No apprehension need to be entertained of the holes made by the auger being filled up, whether the drain is open or covered, unless other waters are admitted; because such is the force of the spring, that it will throw up any stones, earth, or other substances that might accidentally get into it, and it can be injured by nothing, but great quantities coming upon it at once.

“If the drain is to be covered, the mode adopted by Mr. Elkington is, to make it square, either of common brick or stone. Of the two, stone, when flat, is preferable; at the same time, when stone cannot be had, a sort of brick, invented, it is said, by Mr. Elkington, answers the purpose well.

“But

“ But the tax (which certainly ought to be taken off, on bricks for drains) prevents the general use of this article, though so well calculated for the purpose. If the drain is well made, it may last for ages; the force of the running-water preventing it from filling up, more than a spring flowing through the bowels of the earth, provided the mouth of the drain is kept open, and regularly cleaned out when necessary. None of those made by Mr. Elkington have as yet failed; any person who makes in future, may safely engage to keep them in repair for fifty or one hundred years.

“ This system of draining land is sometimes attended with extraordinary consequences. By it, not only the land below the natural spring, or even above the artificial spring, is drained, but the waters from the neighbouring heights, finding a new and easier channel, abandon the places to which they formerly went, and thus a tract of country may be drained, without the least apparent communication with the spring intended to be drained, or the trench made to it. Nay, a drain made on one side of a hill has been known to
make

make springs and wells on the other side quite dry, opening a channel of an easier sort, to which the water naturally draws.

“As yet, Mr. Elkington has only made use of these discoveries for the purpose of draining the land. But as the complete command of an unexpected treasure of water is thus obtained, it is probable, that the plan may be very much improved, by using the water thus obtained for the purpose of flooding land, which it is well known is the greatest of all improvements, as it requires little pains or expence to insure, by means of the water alone, luxuriant crops and perpetual fertility. From springs also such quantities of water may be obtained, as may be of use in regard to mills and navigations, and in supplying private houses, and even towns and villages, with wholesome water to drink, or to use for other purposes, instead of mere puddle.

“Mr. Elkington being extremely successful in judging of the strata of the earth, where it has not been greatly altered by some convulsion of nature, it may be right to state the principles on which he acts.

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His mode of judging of the strata is not from the herbage that grows upon the surface, which is often artificial, and not natural (rushes only excepted, which denote clay) nor, as some imagine, from the morning and evening vapour; but in wet weather he judges by the state of the surface, the veins of clay being then wet, whereas those of sand are comparatively dry. The best mode of determining the matter is, however, by examining the neighbouring heights, particularly if any pits or quarries have been made in them, because, if the one height at all resembles the other, the strata on the same level will probably be the same. He also judges, with remarkable precision, how to find stone in places where it would not be generally looked for, and to discover the place where wells may be made with the best chance of success.—The rules on which he acts in regard to these two articles, must be the subject of future enquiry. The knowledge of the different strata will be greatly facilitated by Mr. Elkington's giving plans of the strata in England, so far as he has travelled through it; the
same

same strata frequently running in a line from sea to sea.

“ On the whole, it appears that this mode of draining land injured by subterraneous waters, is by far the most effectual of any that has yet been suggested; and, to the credit of Mr. Elkington, it is to be observed, that he made no difficulty in communicating the nature of his discoveries to the Committee of the Board of Agriculture, appointed for the purpose of meeting with him upon the subject; and that he left it entirely to the Board to make him any remuneration, or not, as they might judge proper.

“ Mr. Elkington having thus enabled the Committee, to form some idea of his system of draining, and the principles on which it is founded, it only remains to point out the best mode of making others masters of the subject, so that the benefits thereof may be spread as quickly as possible over the kingdom. Mr. Elkington is of opinion, that the most likely plan for that purpose, is, for the Board either to pitch upon some intelligent persons to travel about with him, to whom he will communicate

communicate his ideas, and explain the principles on which he acts more distinctly, by pointing out on each spot, respectively, the manner in which he would drain the different kinds of soil; or to bind apprentices to him, whom he would readily instruct. Perhaps, a tour over the whole island, would be adviseable, beginning with the Eastern, and returning by the Western coasts of the kingdom. Mr. Elkington would thus be enabled to judge, to what extent this mode of improvement could be carried, and whether the same system will answer amidst the hills and vallies of Wales, or Scotland, as in those of Lancashire, where he has already been so successful."

The only remark I shall make on the above is, that it is not easy to form an idea how such a performance could ever have been produced. Perhaps, it may be accounted for on the supposition that the following case could have happened.—If Mr. Elkington, when he met the Committee of the Board of Agriculture at Wooburn-
 2 Abbey,

Abbey, for the purpose of explaining to them the principles of his mode of draining, should have candidly told them, that he was merely a plain practical man, who was little acquainted with philosophical principles of any sort, and therefore was not able to give any kind of explanation such as they seemed to require; that he could not clearly express, perhaps, any of his ideas, so as to make them intelligible to gentlemen of their rank; but, if they would have the goodness to show him a field that required to be drained, he would let them see in what manner he should proceed, and give them the best explanation he could of every thing about which they should interrogate him as he went on; and that this was the only way in which he thought he could make the reasons of his practice be fully understood. Should this, I say, have happened, and should this have been all the information the Committee could obtain from himself; and should they farther think, that after what had happened, it would be absolutely necessary for the Committee to make some *report* to the Board; and should

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they

they thus circumstanced, have charged some person to make out the best account *he could* on this subject; and should that person, who had formed a few vague notions from the imperfect hints of Mr. Elkington ill understood, and mingled with former ideas adopted at school, make out that account; such a production as that which has been above exhibited, might naturally enough have been the result.— I do not say, that this did actually happen; but, I think, it would be difficult to account for such a performance in any other way. It certainly never could have been written by one who had even *attempted* to put his own directions into practice.

In the present edition some additions have been made to this Essay, to render it somewhat more complete than before; but these additions are carefully distinguished from the original performance. These additions, with some others, are printed separately, to be sold for the accommodation of the purchasers of the former editions of this work: and for the sake of other purchasers, who may incline to have the Essay on Draining complete, that Essay

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has

has been there given entire. To which is added, the Two Letters to Sir John Sinclair, illustrative of that subject.

It is hoped, the author will be pardoned for employing the same plates for the separate publication as for the book, though they contain some objects that do not relate to the present Essay.

AND SWAMPY GROUNDS. 67

ON

DRAINING BOGS

AND

SWAMPY GROUNDS.

IN the preceding Essay, I have showed, that water may on some occasions be of great utility to the farmer; yet, as there are few things more prejudicial to him than a superabundance of it, when too long continued upon the ground, it behoves him to guard against this evil as much as he possibly can; and at almost any expence, to free his ground from it, if he hopes to make any considerable improvement thereon; for, unless this be first done, all his other operations will turn out to little account.

The methods of drawing off stagnant water, which may be accumulated in any low situation, for want of a proper outlet, are in general so obvious to every man of discernment, who examines the situation of the ground, that I shall not tire the

reader by enlarging upon that head ; but shall proceed immediately to treat of the most proper method that I have experienced, of draining such ground as is hurt by springs oozing out upon them (usually distinguished by the name of *wet*, or *spouting* ground) and bogs* ; as this is a matter of much greater difficulty than the former, and the principles upon which it should be conducted, far less generally understood.

Springs are formed in the bowels of the earth, by water percolating through the upper strata, where they are of a porous texture, which continues to descend downwards, till it meets with a stratum of clay that intercepts it in its course ; where, being collected in considerable quantities, it is forced to seek a passage through the porous strata of sand, gravel, or rock, that may be above the clay, following the course of these strata till they approach

* It will appear to the reader, that the term *bog*, is here employed in its most unlimited acceptation, denoting any kind of quaggy ground arising from too much moisture ; and not according to the usual meaning of the word in Ireland, where it, for the most part, only denotes what is in Scotland called peat-moss.

the surface of the earth, or are interrupted by any obstacle which occasions the water to rise upwards, forming springs, bogs, and the other phænomena of this nature; which being variously diversified in different circumstances, produce that variety of appearances in this respect that we often meet with.

This being the case, we may naturally conclude, that an abundant spring need never be expected in any country that is covered to a great depth with sand, without any stratum of clay to force it upwards, as is the case in the sandy deserts of Arabia, and the immeasurable plains of Lybia. Neither are we to expect abundant springs in any soil that consists of an uniform bed of clay from the surface to a great depth: For, it must always be in some porous stratum that the water flows in abundance, and it can be made to flow horizontally in that only, when it is supported by a stratum of clay, or other substance that is equally impermeable by water. Hence the *rationale* of that rule so universally established in digging for wells, that if you begin with sand or gra-

vel, &c. you need seldom hope to find water, till you come to clay; and if you begin with clay, you can hope for no water in abundance, till you meet with sand, gravel, or rock.

It is necessary that the farmer should attend to this process of nature with care, as his success in draining bogs, and every species of damp and spouting ground, will in a great measure depend upon his thorough knowledge of this,—his acuteness in perceiving in every case, the variations that may be occasioned by particular circumstances, and his skill in varying the plan of his operations according to these. As the variety of cases that may occur in this respect, is very great, it would be a tedious task to enumerate the whole, and describe the particular method of treating each; I shall, therefore, content myself with enumerating a few particular cases, to shew in what manner the principles above established may be applied to practice.

Let Fig. 21st represent a perpendicular section of a part of the earth, in which AB is the surface of the ground, beneath
which

AND SWAMPY GROUNDS. 71

which are several strata of porous substances, which allow the water to sink through them till it reaches the line CD, that is supposed to represent the upper surface of a solid bed of clay; above which lies a stratum of rock, sand, or gravel. In this case it is plain, that when the water reaches the bed of clay, and can sink no farther, it must be there accumulated into a body; and, seeking for itself a passage, it will flow along the surface of the clay, among the sand or gravel, from D towards C, till at last it issues forth at the opening A, a spring of pure water.

If the quantity of water that is accumulated between D and C is not very considerable, and the stratum of clay approaches near the surface, in that case, the whole of it will issue by the opening at A, and the ground will remain dry, both above and below it. But if the quantity of water is so great, as to raise it to a considerable height in the bed of sand or gravel, and if that stratum of sand is not discontinued before it reaches the surface of the ground, the water in this case, would not issue at A only, but would like-

wife ooze out in small streams through every part of the ground, between A and *a*; forming a barren patch of wet sandy or gravelly ground upon the side of a declivity: Which is a phænomenon that every attentive observer must have frequently met with.

To drain a piece of ground in this situation, is perhaps, the most unprofitable task that a farmer can engage in; not only because it is difficult to execute, but also, because the soil that is gained is but of very little value. However, it is lucky that patches of this kind, are seldom of great breadth, although they sometimes run along the side of a declivity, in a horizontal direction, for a great length.

The only effectual method of draining this kind of ground, is, to open a ditch, as high up as the highest of the springs at *a*, which should be of such a depth as not only to penetrate through the whole bed of sand or gravel, but also to sink so far into the bed of clay below, as to make a canal therein, sufficiently large to contain and carry off the whole water. Such a ditch is represented by the doted lines *a*,

e, z;

c, *z*; but as the expence of making a ditch of such a depth as this would suppose, and of keeping it afterwards in repair, is very great; it is but in very few cases that this mode of draining would be adviseable, and never, unless where the declivity happens to be so small, that a great surface is lost for little depth; as would have happened here, if the surface had extended in the direction of the doted line *a d*.

But, supposing that the stratum of clay, after approaching to the surface at *A*, continued to keep at a little depth below ground; and that the soil which lay above it was of a sandy or spongy nature, so as to allow the water to penetrate it easily: In that case, even supposing the quantity of water that flowed from *D* to *C*, was but very inconsiderable, instead of rising out at the spring *A*, it would flow forward along the surface of the clay, among the porous earth that forms the soil, so as to keep it constantly drenched with water, and, of consequence, render it of very little value.

Wetness, arising from this cause, is usually

usually of much greater extent than the former ; and as it admits of an easy cure, it ought not to be one moment delayed. For a ditch of a moderate depth opened at A, and carried through a part of the stratum of clay (as represented by the dotted lines A, k, f) would intercept and carry off the whole of the water, and render the field as dry as could be desired. It is, therefore, of very great consequence to the farmer, accurately to distinguish between these two cases, so nearly allied to each other in appearance ; and as this can be easiest done by boring, every one who has much ground of this kind, ought to provide himself with a set of boring-irons, which he will likewise find use for on other occasions.

I might here enumerate a great variety of cases which might be reduced to the same head with the foregoing : but as any attentive reader may, after what has been said, be able easily to distinguish these, I shall only in general observe, That every soil of a soft and porous texture, that lies upon a bed of hard clay, whatever its situation in other respects may be, will in
some

some measure be subjected to this disease : And if it is upon a declivity of any considerable length, the undermost parts of the field will be much damaged by it, unless ditches are thrown up across the declivity, at proper distances from one another, to intercept the water in its descent.

It may not likewise be improper here to remark, that, in cases of this nature, unless where the soil is of a very great depth, the malady will always be encreased, by raising the ridges to a considerable height ; as will appear evident by examining Fig. 22, in which the line AB represents the surface of a field of this nature, and CD the surface of the bed of clay. Now, if this field were raised into high ridges, as at F, F, F, so as that the furrows E, E, E, descended below the surface of the clay, it is plain, that all the water that should sink through the middle of the ridge, would run along the surface of the clay, till it came to the sides of the ridge L, L, L, L, L, L, which would thus be kept continually soaked with water ; whereas, if the ground had been kept level,

vel, as in the part of the field from G to H, with open furrows H, at moderate distances from one another, the water would immediately sink to the clay, and be carried off by the furrows, so as to damage the soil far less, than when the ridges are high.

If the soil is so thin, that the plough can always touch the clay, the ridges ought to be made narrow and quite flat, as from G to H; but if there is a little greater depth of soil, then it ought to be raised into ridges of a moderate height, as from H to K, so as to allow the bottom of the furrow to reach the clay. But neither is this necessary, where the soil is of any considerable depth.

I have seen some industrious farmers, who having ground in this situation, have been at the very great expence of making a covered drain in each furrow. But, had they rightly understood the nature of the disease, they never would have thought of applying such a remedy; as must appear evident at first sight to those who examine the figure. The success was, what

what might be expected from such a foolish undertaking.

These observations, it is to hoped, will suffice as to the manner of treating wet, sandy, or porous soils. I now proceed to take notice of such as are of a stiff clayey nature, which are often very different in appearance, and require a different treatment from these.

Suppose that (as in Fig. 23) the stratum of sand or gravel, D C, should be discontinued, as at E, and that the stratum above it should be of a coherent clayey nature: In this case, the water that flowed towards E, being there pent in on every side, and being accumulated there in great quantities, it must, at length, force a passage for itself in some way; and pressing strongly upon the upper surface, if any one part is weaker than the rest, it there would burst forth, and form a spring (as, suppose, at A). But if the texture of every part of this stratum were equally strong, the water would squeeze through many small crannies, and would ooze out in numberless places, as between A and R, so as to occasion that kind of wetness
which

which is known by the name of a spouting clayey soil.

The cure, in this case, is much more easily effected than in any of the former : For, if a ditch of a considerable size be opened, as at A, towards the lowermost side of the spouting ground, so deep as to penetrate through the upper stratum of clay, and reach to the gravel, the water will rise up through it, at first, with very great violence, which will gradually decrease, as the pressure from the water behind is diminished. And when the whole of the water accumulated in this subterraneous reservoir is run off, there being no longer any pressure upon the clay above it, the whole soon becomes as dry as could be desired ; and continues so ever afterwards, if the ditch be always kept open. This I speak from experience, I having rendered some fields of this kind that were very wet, quite dry, by this method of treating them.

It will hardly be necessary for me here to put the farmer upon his guard, to be particularly careful in his observations,
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that he may distinguish between the wetness that is produced from this cause, and that which proceeds from the cause before mentioned: Because the treatment that would cure the one, would be of no use at all to the other.

The attentive observer, likewise, will readily perceive, that if any field that is wet from this cause, admits of being ploughed, it will be in equal danger of being hurt by being raised in high ridges, with the other kind of damp ground before mentioned: For, as the depth of earth above the reservoir would be smaller in the deep furrows than any where else, there would, of consequence, be less resistance to the water in that place, so that it would rise there in greater abundance. And if, in this case, a farmer should dig a drain in each furrow;—as a considerable quantity of water would rise into them, in some cases, the ground might be improved, or even quite drained thereby, (especially if they should have accidentally reached the gravel in any other place,) although at an expence much greater than]

than was necessary *. I take notice of this circumstance, in some measure, to prevent the prejudice that some inattentive observers might entertain against what we said before of this method of draining, from their having accidentally seen some fields that may have been bettered by it.

Bogs are only a variety of this last-mentioned kind of wet ground, and therefore ought, in general, to be drained after the same manner with them. Clay is a substance that strongly resists the entrance of water into it; but, when clay is long drenched with water, it is, in process of time, in some measure, dissolved thereby, loses its original firmness of texture and consistence, and becomes a sort of semi-fluid mass, which is called a bog. And as these bogs are sometimes covered with a surface of a particular kind of grass, with very matted roots, which is strong enough

* This seems to have been precisely the case, in the first attempt of Mr. Elkington at draining, in which case he *accidentally* penetrated the bed of clay, and reached the pervious stratum below it.

to bear a small weight without breaking, although it yields very much, it is, in these circumstances, called a *Swaggle*.

But whatever be the nature of the bog, it is invariably occasioned by water being forced up through a bed of clay, as just now described, and dissolving, or softening, if you will, a part thereof. I say only a part, because, whatever may be the depth of the bog, or swaggle, it generally has a partition of solid clay between the bog and the reservoir of water under it, from whence it originally proceeds: For, were not this the case, and were the quantity of water considerable, it would meet with no sufficient resistance from the bog, and would issue through it with violence, and carry the whole semifluid mass along with it. But this would more inevitably be the case, if there was at first a crust at the bottom of the bog, and if that crust should ever be broken; especially, if the quantity of water under it were very considerable. And as it is probable, that in many cases of this sort, the water slowly dilutes more and more of this under-crust, I make no doubt but that in the revolution of many ages, a

great many irruptions of this kind may have happened; although they may not have been deemed of importance enough to have the history of them transmitted to posterity*.

Of this kind, although formed of a different substance, I consider the flow of the Solway moss, in Cumberland, to have been; which, upon the 16th November, 1771, burst its former boundaries, and poured forth a prodigious stream of semi-fluid matter, which, in a short time, covered several hundred acres of very fine arable ground. Nor will any one who is acquainted with the nature of moss, who knows its resemblance to clay in its quality of absorbing and retaining water, and its very easy diffusibility therein, be surprised at this; as, from all these properties, it is much better adapted for forming an extensive bog, and therefore in greater danger of producing an extensive devastation, by an eruption of the water into it,

* Probably, the eruption which produced Saint Winifred's well, in North Wales, may have been of this sort. *Note to the fourth Edition.*

than

AND SWAMPY GROUNDS. 83

than those that are formed of any kind of clay whatever *.

If the bog or swampy ground be upon a declivity, the ditch ought to be carried across the field, about the place where the lowest springs arise. But if the surface of the ground be level, or nearly so, as between A and B (Fig. 24) and the springs break out in several places, *q q q q q q*, so as to form soft quagmires interspersed through the whole of the field, it will be of

* Since the above was written, I find the eruption of Solway-moss was produced in a manner very different from the above. The water which carried it off, insinuated itself between the smooth bed of clay, below the moss, in such great quantities, as, without softening the moss so as to reduce it to the state of a semi-fluid mass, heaved it up, so as to be as if afloat upon the water, which shoved it bodily forward with the current, till it was left, in a great measure, in its natural state, lying above the corn-fields, to the whole depth of the moss. For farther elucidations on the subject of moss, see a Practical Essay on Peat Moss. Robinsons, 1794.—

N.B. At the time the present Essay was written, I had formed no distinct idea of the nature of moss; and at the time the Essay on moss was written, I knew nothing of the fact here stated. It affords an additional proof of the truth of the hypothesis there brought forward. *Note to the fourth Edition.*

little consequence in what part the drain is opened; for, if it be dug so deep as to allow the water to rise in it with freedom, it will issue through that opening, and the field will be left perfectly dry.

But as it may frequently happen that the stratum of gravel shall be at a considerable depth beneath the surface of the earth, and as it may be sometimes even below the level of the place into which the drain must be emptied, it might sometimes be extremely difficult to make a ditch so deep as to reach the bed of sand or gravel. But it is lucky for us that this is not absolutely necessary in the present case; because a drain, of two or three feet deep, as at D, will be equally effectual with one that should go to the gravel. All that is necessary in this case is, to sink pits (P) in the course of the drain, at a moderate distance from one another, which go so deep as to reach the gravel. For, as the water there meets with no resistance, it readily flows out at these openings, and is carried off by the drain, without being forced up through the earth; so that the ground is left entirely dry ever after.

I have

I have likewise drained several fields in this way; and as I have generally found the appearances pretty much alike, I shall, for the information of the inexperienced reader give a short account of them :

If you attempt to make your pit in one of these soft quaggy places, where the water is found in great abundance, you will meet with very great difficulty in forming it: For, as the substance of which it is composed is a semi-fluid, it will always flow into the hole as fast as you dig it. On this account, I would advise, not to attempt to make the pit in the swaggle, but as near it in the solid earth as you conveniently can. However, if it be pretty firm, and of no great extent, it will be sometimes practicable to make a pit in the soft bog, at the driest time of the year. This I have sometimes practised, which gave me an opportunity of observing the nature of these bogs more perfectly than I otherwise would have had.

In the trials of this kind that I have made, the soft quaggy ground has seldom been above three or four feet deep, below which I have always found a stratum of

hard tough clay, usually mixed with stones, and so firm that nothing but a mattock or pick-axe could penetrate it: And as this stratum is comparatively much drier than the ground above it, an inexperienced operator will be very apt to imagine that it is the bottom he is in search of.

In digging through this stratum, you will frequently meet with small springs oozing out in all directions; some of them that might fill the tube of a small quill, and others so small as to be scarcely perceptible. But, without regarding these, you must continue to dig on without intermission, till you come to the main body of the reservoir, if I may so call it, that is contained in the rock, gravel, or sand; which I have generally found from two to four feet below the bottom of the swaggle, and which you will be in no danger of mistaking when you come to it. For, if there has been no opening made before that time in the field, as soon as you break the crust immediately above the gravel or rock, the water will burst forth like a torrent, and, on some occasions, will rise like

like a *jet d'eau*, to a considerable height above the bottom of the ditch; and continue to flow off with great impetuosity for some time, till the pent-up water being drained off, the violent boiling up will begin to subside, and the strength of the current to abate, and in a short time it will flow gently out like any ordinary spring.

Allowing it to remain in this state for some time, the quaggy earth will soon begin to subside, and gradually become firmer and firmer every day; so that in the space of a few months, those bogs that were formerly so soft, as hardly to support the weight of a small dog, will become so firm, that oxen and horses may tread upon them without any danger of sinking, at the very wettest season of the year.

I had a field of this nature, that, by having only one such pit, as I have now described, opened in it, was entirely drained, to the distance of above a hundred yards around in every direction.

But, as it is possible that the stratum in which the water runs, may be in some places

interrupted, it will be in general expedient to make several of these pits, if the field is of great extent; always carrying the drain forward through the lowermost part of the field, or as near the quag as you conveniently can; and sinking a pit wherever you may judge it will be most necessary. But if the stratum of gravel is not interrupted, there will be no violent burst of water, at opening any of these after the first, as I have frequently experienced.

To keep these wells from closing up, it is always expedient to fill them up with small stones immediately after they are made, which ought to rise to the height of the bottom of the drain.

I have often imagined, that the expence of digging these pits might be saved, by boring a hole through this solid stratum of clay, with a large wimble (auger) made on purpose; but as I never experienced this, I cannot say whether or not it would answer the desired end exactly.

If the whole field that is to be drained, consists of one extensive bog, it will require a long time before the whole work can be entirely finished; as it will be im-

possible to open a drain through it, till one part of it be first drained, and becomes solid ground. In a situation of this kind, the undertaker, after having opened a drain to convey the water from the lowest part of the bog, must approach as near to the swampy ground as he can, and there make his first pit, which will drain off the water from the nearest parts of the bog.

When this has continued open for some time, and that part of the bog is become so solid as to admit of being worked, let him continue the ditch as far forward through it as the situation it is in will admit of, and there sink another pit; and proceed gradually forward in the same manner, making cross cuts where necessary, till the whole be finished.

In this manner, may any bog or tract of spouting ground, of this nature, be rendered dry, at a very inconsiderable expence. And as there can be no other method of draining ground of this sort effectually, I recommend the study of it to the attention of every diligent farmer who may have occasion for it. Let him first be extremely

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ly cautious in examining all the circumstances of his particular fields, that he may be certain which of the classes above enumerated it may be ranked with; and when he is perfectly sure of that, he may proceed without fear, being morally certain of success.

There is, however, one kind of damp ground, not yet particularly specified, that I have purposely omitted taking notice of till this time, as I have never had an opportunity of examining particularly into the nature of it, nor of ascertaining, by experience, what is the most proper method of treating it.—The soil I have now particularly in my eye, consists of a deep strong clay, that does not vary its nature even on the surface, but in as far as manures may have rendered it more friable and tender. The colour usually inclines to a reddish cast; and, for the most part, it is situated upon the side of some declivity. This bed of clay reaches to a great depth, without any variation, and is, on many occasions, intermixed with a considerable quantity of small stones.

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Many soils of the sort now described, are apt to be continually moist, and full of water, during the winter season. But when the dry weather of summer sets in, the moisture is diminished, and the surface becomes hard; and it is rent into many large gaps, which allow free admission to the sun and air, so as to scorch up almost every plant that is sowed upon it. And as these soils are usually, in themselves, naturally fertile when drained, it were to be wished that some method could be discovered that would be less expensive than what is usually practised with regard to some soils of this kind in Essex, where they make covered drains of two feet and a half deep, running diagonally through the whole field, at the distance of twenty feet from each other.

Were I to indulge myself in conjecturing, I might here offer some remarks tending to show the probable cause of this phenomenon, and point out an easier method of cure. But as it is extremely dangerous for one who pretends to instruct others, to give way to the tempting seductions

tions of a warm imagination, I shall content myself with having pointed out this evil to those who may have it in their power to examine into the causes of this particular malady, and to point out to others the easiest and most efficacious cure.

Here ends the Essay, as it was originally printed.

ADDITIONS

ADDITIONS

TO THE

ESSAY ON DRAINING,

MADE IN THE YEAR 1797.

I AM no longer restrained by the considerations which influenced me when this Essay was first published; an experience of more than twenty years farther has removed those scruples entirely: And though the attentive reader will find little in what follows that may not be inferred from what has gone before, yet it will not perhaps prove disagreeable, to see how the few simple principles above succinctly developed, may be easily applied in some practical cases which assume a considerable diversity of appearance.

The peculiar species of wet land, that has been just now described, is not in general occasioned by springs; for in the kind of soil here described, springs, properly so called, are rarely to be found;—it originates, for the most part, entirely from water that falls from the clouds. When rain falls in
abundance

abundance upon a field of the kind here described, a part of the water will find its way along the surface towards the furrows, if any such have been made in it, by which it will be carried off the field; but a considerable quantity of water will be absorbed by the porous soil on the top, through which it will gradually sink, till it reaches the solid bed of clay below, which, having never been opened up effectually, resists the water, which can there penetrate downwards no farther. In that case, it can find no outlet until it forces its way laterally towards the furrows, slowly through the superficial mould—or, if no furrows are provided to carry it off, it must remain as in a basin, in which the superficial soil is mixed with the water, so as to become a thin paste, that must remain of a soft consistency during wet weather, and which, when much rain hath fallen, will be only a small degree removed from fluidity—While in this state, it must be highly prejudicial to the vegetation of all those plants we are in the use of cultivating in this country: But in this state the soil must remain, drenched with water, until the return of dry weather. The sun will then evaporate

evaporate it; when the soaked paste, now deprived of its moisture, will assume a hard irony consistence, which is equally unfit for the sustenance of plants as it was in its moistened state.

Such being the causes of this disease, the consequences may be easily removed. The opening up of hollow drains, running diagonally across the slope, at a small distance from each other, if they can be kept open, will answer the same purpose, nearly, that the drawing of open water furrows in the same direction would have done, and will, doubtless, mitigate the evil, in proportion to their nearness to each other: but they must be very close together indeed, if they remove it entirely—for still the soil must be drenched in the manner before described, by the water forcing its way through it, until it reaches the drain.

But, as the rain-water will sink perpendicularly through the soil, until it meets with the solid clay, before it attempts to seek a lateral direction, it must follow that that part of the mould which is nearest to the clay, will be more drenched with water than those parts of it which lie at a
greater

greater distance above the clay ; of course, the deeper the soil, the less will the surface-mould be liable to be drenched with hurtful moisture.—Hence it follows, that if the soil shall be deepened to such a degree, as that the water, even during the greatest rains, shall not be forced to rise so high as to chill the roots of the plants which grow upon it, the remedy wished for will be effected.

Nor will this be a matter of such great difficulty, as at first sight it might appear—for as the rain sinks slowly downward through such a soil, that portion of rain which falls first continuing to sink regularly, if the soil be mellow, without stopping, goes gradually downward, making way for that which follows, without being regorged back upon it till it meets the bottom—Hence, if we should suppose, for the sake of illustration, that the rain sunk four inches downward in twenty-four hours, and that the rain continued without intermission for three days together, the water would have penetrated, by that time, to the depth of twelve inches, had it met with no interruption before the rain abated ; but
if

if the soil were no more than four inches deep, the water would have reached the bottom, in twenty-four hours, after which time, it could go no farther—but the rain continuing to pour on more, the soil towards the bottom, by acquiring fresh additions of water every moment, is there soon reduced to the state of a semi-fluid paste; and as the water must rise higher and higher, while the rain continues, more of the soil must be drenched by it, until the whole soil becomes like a soft pap, that is incapable to support the smallest animal. Or, if the open furrows or under-drains be near at hand, a part of the water will at last fall into these, and be carried off the field, after having washed the surface-mould in its passage so as thus to carry off with it all the soluble parts of the manures it has met with in its course. But if the penetrable mould had extended to a greater depth (say sixteen or twenty inches) the water would not stop even when the rain abated, but continue to sink farther, till at last it would be all imbibed by the earth, without having reduced any part of it to the state of a pap—and even without the aid of any drain

H whatever.

whatever. Thus would the mould, having never been reduced to the state of a paste, continue friable, even when dry weather approached: and as the roots of plants growing upon the soil would thus be invited to stretch to a great depth, they would there find moisture sufficient to sustain them, at a time when, if they had been forced to spread abroad near the surface, for want of depth of soil, they must have perished from lack of moisture. In this way, the soil is rendered dry in moist weather, and moist in dry seasons, to a degree that could not otherwise have been experienced. And, as it has been already said, the water in its progress dissolves and carries along with it, a portion of the vegetable manures, this portion of manure, by the process now described, is all left in the soil, and of course tends to meliorate it, instead of being carried off from it either by the water-furrows or the drains, which becomes indispensably necessary, where the soil is thin—and which unavoidably reduces it into that poor hungry state so frequently experienced under circumstances of the sort here described.

There are found in many counties of

Great Britain, immense tracts of poor, hungry, clayey soils, that are all reducible to the class of which we now treat.—They have been denominated *hungry*, from the sudden disappearance of the effects of manures that have been laid upon them; they are also called *hide-bound*, because of the hard stiffness, and miserable appearance of the surface. Few soils are, in their present state, more unprofitable than those. Yet there are, perhaps, none, which, under a judicious management, could be rendered more productive than many of them. It often happens, that over the whole surface of such soils, a thin crop of weakly rushes are produced, while it is allowed to remain in grass; and fog or moss, which establishes itself there during the winter months, is almost the only vegetable production, that gives a sickly verdure to the surface. Upon examination, it will be found, that in all cases of this sort, the unloosened clay rises very near to the surface; in consequence of which, the superficial mould, which has been stirred by the plough, to a small depth only, being thinly spread over it, is subject to be drenched

through its whole depth by every violent rain, the manures completely washed out of it, and the whole reduced to a pappy paste, that becomes hard like iron, when the summer heat dissipates the moisture. Under these circumstances, whatever manures or culture are bestowed upon it, are in a great measure, thrown away, as they are seen to produce but very little effect; and these soils, are therefore, in a great measure, abandoned as hopeless.

Many soils of this description, however, if opened to a sufficient depth, may be gradually brought into a state of great productiveness. Indeed, many of the most productive districts in this kingdom consist precisely of soils that were originally of this kind. When such soils are thus opened up, they are, for the reasons above assigned, more effectually drained than they could be by any other process. The manures that are, after this is done, worked into the soil, are never carried off from it, but gradually tend to meliorate, and thus to render more tender and friable, the bottom soil; so as, in time, to become deep, sound, and wholesome land, which is
neither

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neither strongly affected by the vicissitudes of drought nor of rain.

These effects, however, are not to be expected to be felt at first, to their full extent. Some clays are so cohesive, that mere digging alone will not render them as permeable by water, as could be wished. Before they can become sufficiently friable for the purpose, to the highest degree that could be wished, manures must have had time to operate upon them. For this reason, although the effect of deep digging, and copious manuring, will be at once sensibly felt, yet the melioration that will result from this process, will be going forward for many years to come; and, by degrees, it will be coming nearer and nearer to that highest degree of productiveness for which the old lands of that description, above named, are so very remarkable.

We have an opportunity of observing the effect of thus opening the soil to a great depth, in our gardens, which, in consequence of being universally trenched over, as an initiatory step, are found to continue healthfully dry, even in soils of

this kind, without the aid of either water-furrows, to carry off the surface-rain, or hollow-drains, to carry off the moisture from below. If there be but one drain leading from the lowest part, to allow the little water that *seeps** down to it, to be carried freely away, that is quite enough to preserve the mould healthfully dry. But in fields where the plough can penetrate to a much smaller depth, it is found universally, that many water-furrows are absolutely required, before such a soil can be prevented from sustaining great damage from the pasting process above described; and that hollow-drains are likewise required to aid them, before the ground can be made tolerably healthful.

I may be permitted to observe, however, that in most cases of this sort, where the surface-mould is no deeper than the plough goes, hollow-draining becomes necessary only in consequence of the ridges being laid in an improper direction; for, when the furrows lie directly up and down

* Is *seeps* an English word? It means to flow gradually, and in very small quantities through some resisting medium.

the declivity, it is easy to observe, that whatever water sinks through the mould, will have a tendency, when it reaches the clay, to run forward among the foil towards the bottom of the hill, rather than to force a passage for itself laterally towards the furrows.—In consequence of this, the foil, especially towards the middle of the ridge, in particular where the declivity is considerable, will be drenched with water nearly as much as if no water-furrows were left in the field. To intercept that water therefore, in its descent, hollow-drains, that run assant the ridges, become absolutely necessary.—If the furrows had been laid in the same direction with the drains, nearly the same benefit would have resulted from the furrows as the drains afford. And were it not for the inconvenience that is felt in ploughing in that direction, these furrows would even operate more efficaciously, in most cases, in drying the ground, than the drains. For, it must be observed, that in making hollow-drains, it becomes necessary that they should not be so far filled with brush-wood, or other porous matter,

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through which the water can be permitted to sink easily, as to reach the plough-furrow ; otherwise that matter would be deranged by its operations, and in such stiff mould, the earth that is put above the brush-wood is apt to cake, and become solid, so as to resist the entrance of water into the drain. This is a very serious evil, which every person who has land in that situation, must have often experienced. Open furrows are entirely freed from all danger of this sort. Where dry peat-dross can be obtained in abundance, for filling the drains at top, this inconvenience would be obviated. See Treatise on Peat Moss.

But, although the facts above stated sufficiently evince, that the loosening the surface mould to a sufficient depth, in a soil of the nature here treated, will, in most cases, prevent the necessity of under-draining of any sort, and in *all* cases will effect a great and radical improvement ; —yet I wish not to be understood to say, that under-draining will not prove, in some cases, useful. But even in those cases where they may prove useful, the number
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of drains wanted, will be prodigiously diminished. If the process above recommended be adopted, one drain will, under these circumstances, do more good than a hundred would do without it—(indeed, no number of drains whatever could so effectually meliorate the soil) and, it deserves to be remarked, that where such a drain shall be made, the evil just stated may be entirely obviated; for as the plough never reaches near to the bottom of the mould, the hollow-drain may be filled quite to the top of the clay, or even above it, with porous matter, without any risk of its being deranged, and it will, of course, keep always open, to receive any water that may have occasion to fall into it.

As to the most adviseable mode of deepening the soil, many considerations require to be adverted to, before that can be determined. In general, the surface-mould is more mellow than any of the bottom soil, on which account, it ought not to be buried by trenching it down; the effects of which, upon a very stiff clay, where manures are not extremely abundant,

dant, can very slowly be overcome. In such cases, it will be more adviseable, after having turned over a large and deep furrow of the surface-mould, to make men follow, in the same furrow, with spades, and dig it over, without turning it upon the top; or loosen it to a considerable depth, with an implement which may be called a *crow-spade* (being a small iron crow, sharpened at the point, into the form of a very narrow-pointed spade, not exceeding three inches at the broadest part) having a foot-piece projecting from the stalk, and a cross handle of wood at top, which I have found to be a strong handy tool for works of that kind. Where the soil is perfectly free from stones, a kind of plough, having a share and cutters only, for loosening without turning over the soil, may be made to follow the other plough, in the same furrow, an implement which has been lately introduced into Lancashire, under the name of the *miner*. This kind of under-mould loosening ought to be repeated from time to time, when it is perceived to get bound below; but the surface-mould should always be preserved
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at top. In most cases, where circumstances permit of it, the friability, dryness, and productiveness of such a soil will be greatly promoted by a *copious* admixture of lime or other calcareous matter with it. The *quantity* can scarcely be too great; but on such soils a dressing of a chaldron or two of lime per acre, will be so disproportionately small, as to produce scarcely any sensible effect. In every case, soils of this nature admit of, and in their poor state require, a more abundant manuring than any others. After they have been thus enriched and meliorated by time, they will produce greater crops than any other soil, even with a moderate quantity of manures.

It would be foreign from the scope of this Essay to enter more fully into the proper mode of managing such soils, or of peculiarising with great nicety the diversity of soils that all belong to this general class. These diversities are very great, and some kinds will repay the expence much sooner than others. It is the proper business of the husbandman to distinguish these; it only belongs to me here to say,

say, that *all* of them will be greatly benefitted by the process recommended. Neither must I here stop to explain in greater detail the most economical ways in which the soil may be opened up, I shall only in general add, that deep ploughing, in the ordinary operations of tillage, *at every time it is stirred*, is by no means necessary.—(See farther on this subject, *Essays on Agriculture*, vol. iii. p. 298.)

I cannot omit, however, on this occasion, to take notice of the absurd impolicy of that rule which prevails in most counties in England, of prohibiting grass lands from being ploughed. In all cases of this sort (and many millions of acres of this description of land are found lying in the most unprofitable kind of grass) it is the same thing as dooming the best land to a state of perpetual sterility—for such land, when suffered to lie in its natural state, produces next to nothing in grass; yet by a spirited and judicious mode of culture, continued for a sufficient length of time, it becomes the most productive of all soils. I could easily point out soils of this kind, which, if left to grass, in their natural state, never could have yielded half a crown of

rent per acre, that have been brought, in the space of a few years, to yield crops of wheat from seven to nine quarters per acre; a weight of crop that no soil I know, but those of which I now treat, could ever be made to produce.

Were I to call those improvements, *discoveries*, which are merely the result of the exercise of the common powers of reasoning from facts that daily occur; and were I to value such discoveries in proportion to the extent of their utility to mankind, I should perhaps reckon the above one of the most important discoveries that has been made in the art of draining in the present age; because, for *one acre* of land that can be drained by means of tapping, there are perhaps several *thousands of acres* in this island which may be benefitted in a very high degree by this very simple process. Indeed, unless it were for the surprize that the mode of draining on the principle of tapping excites, at first, upon the mind of those who have not adverted to things of this kind, and the quickness of the effect it sometimes produces, at little or no expence, where *it is well understood*, and properly

perly applied, it must hold an inferior rank to many other modes of draining that have been long practised, because of the much smaller *extent* of the evil that can thus be removed than by many of the other modes of draining that are developed in this Treatise. More mischief is often produced by a single spring, in the case I am just about to illustrate, than is experienced in a whole county by that peculiar kind of wetness which *can* be removed by tapping. Of the bogs that are found in this island, perhaps not one-thousandth part of them could be reducible to that class which admits of being cured by tapping. I now proceed to give a few additional illustrations, with a view more clearly to elucidate the principles already explained.

As the whole success of practical draining depends upon accurately discriminating between the cases already stated (though, perhaps, with too much brevity) in the foregoing parts of this Essay, my chief aim in these Additions, shall be, so to mark these cases, as to enable the reader to distinguish them. This he will find no difficulty to do where the case
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is *simple*; but in compound cases, he may be, on some occasions, a little at a loss. These difficult cases are, however, very rare, and if he be attentive, he will, after a few trials, be easily able to discriminate them also.

Let the reader never lose sight of the fundamental principle, that all springs are produced in consequence of the water which falls from the atmosphere, upon high grounds, sinking through some kind of porous earth, until it comes to a bed of clay or granite, or other matter that is impervious to water, stopping it from sinking farther, and, of course, forcing it either to rise upwards, as in a reservoir, till the cavity be filled, or making it find a passage through subterraneous pervious strata, till it reaches the surface of the earth, where, according to the circumstances of the case, it either issues at once a pure stream of clear water, running forward in rills to the nearest streams, or oozes obscurely forth through innumerable small orifices, into the porous vegetable mould, which produces that wet weeping

weeping appearance, denominated *spouting ground* or *bogs*.

It will be unnecessary here to accumulate particulars, respecting clear springs. In general, where these occur, little more is required by the farmer, than that the channel be so opened up, as to allow that water to flow off in a free current, in the direction that nature points out; in such a way, however, as never to force it, or even to permit it to be absorbed and lost in the soft vegetable mould that may chance to lie in its way on its passage towards the sea.

And here I may be allowed to observe, that those who wish to get a clear idea of the principles of draining, will do well to begin their studies in mountainous or uneven countries, rather than in plains; for, in the first case, they will meet with many facts, that are obvious on a slight inspection, which cannot, without great difficulty, be made apparent in a flat country. It is, perhaps, owing to an inattention to this circumstance, that so few men who have *practised* draining, have understood the principles of their art; which is doubtless the

the cause of those numerous failures that have been experienced in the *practical* efforts of those, who, in certain cases, have performed cures, that merited the highest degree of applause.

Where a stratum of sand, rock, gravel, or other porous matter, lies in a regular slope towards the earth's surface, supported by a bed of clay (as in Fig. 25) if that stratum has not been deranged by earthquakes, or other violent convulsions of nature, it usually stretches back to a great distance, perhaps at a great depth beneath the surface of the hill, and where it crops out, as at A, if the stratum runs in a horizontal position (which is often the case) when viewed at right-angles to the section here given (which exhibits the natural dip of the strata) it there forms a kind of zone, running along the brow of the hill, nearly in a horizontal direction, for a great way. I have often thus seen a zone of this kind, running along the brow of a hill, nearly at the same height, for miles together; its course being marked every where, by a wet uncomfortable stripe, of inconsiderable breadth, frequently broken into small holes, by the feet of cattle, or

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other

other accidental circumstances. Wherever this indication appears, you may, with next to a moral certainty, conclude, that the evil originates from this source, and you may, therefore, boldly adopt the mode of cure that has been already indicated for this evil; see page 72. A small ditch opened all along the lower part of the spouting zone, that shall be, in every case, so deep as to pass through the pervious mould, and shall penetrate into the bed of clay, or other impervious stratum below, will with certainty intercept the water, and remove the evil, in as far as affects the lower grounds.

Those who have not turned their attention to this subject, will scarcely be able to form an idea of the benefit that may be derived from this simple and easy process. I have frequently seen, in commons, and other neglected places, where the hand of industry has never been exerted (especially in Wales) that a spring of this kind has drenched fields for miles together, rendering the soil one universal cold soft kind of swamp, unfit for producing any kind of vegetable, that is nutritious either for man
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or beast ; for wherever the surface soil is so tender as not to be capable of carrying the water, it sinks through that, and endeavours to force a passage for itself towards the bottom of the hill, along the top of a bed of clay, frequently mixed with stones, that will, in general, be found at no great depth beneath the surface. And as this water is thus interrupted in its course by the resistance of the quaggy mould, it is alternately seen to rise upwards, running through small pores, till it flows forwards a little on the surface, and then sinks downwards through the soil again. Millions of acres of land have I seen, that have lain in this neglected state for ages, which is unfit for any thing else except that of rotting the few miserable sheep that are suffered to straggle along its surface, and might be drained at an expence that is inconceivably small.

All that is required for draining land in this state, is to cut ditches across the slope, nearly in a horizontal direction, giving them merely so much dip as to allow the water to run off through them freely. These drains must always penetrate, at least, one foot or more, in proportion to the quan-

tity of intercepted water, into the solid bed, below the soft surface-earth; and this surface-earth seldom exceeds one foot in depth. The earth that is taken out of these ditches, where it is not meant that it should be made to serve as a fence, ought always to be laid upon the *lower* edge of the bank. There, by its weight, it will serve to consolidate the earth on the lower lip of the ditch, which will make it better resist the entrance of the water, in time of floods, when the ditches may be fuller than usual.

No sooner will such a ditch be made, than the water will be seen to trickle into it, from the higher side, through the whole depth of the mould; but it will also be seen to flow most freely immediately above the clay. The lower part of the field, thus deprived of the sources that used to supply a perpetual moisture, will, in a short time, become drier than before; but it will require a considerable length of time to allow the whole water gradually to drain from it. And as the water that is nearest the ditch must pass through the whole of the soft ground
I below,

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below, before it can make its escape, it is evident that if the slope be long, it will require a great while to free the lower parts from wet. To facilitate this operation, other drains of the same sort should be drawn, nearly parallel to the first, at small distances (from one to two hundred yards) below each other. This will not only accelerate the operation, but it will also enable you to intercept, and thus to discover, any concealed springs that may accidentally break forth in any part of these neglected wastes.

I would here mention, that if in driving your ditch, you should accidentally cross a bed of sand that lies deeper than the bottom of the earth, care must be taken to obviate this evil, were it not so apparently necessary as scarcely to deserve being mentioned. The way of obviating this evil will be gathered from the general tenor of this Essay, and need not be here particularly specified.

When a bed of sand, which serves as a receptacle of springs, instead of terminating abruptly on the surface, as at A, Fig. 25, extends to a considerable distance,

in a direction nearly horizontal, as from A to B, Fig. 26, the circumstances will vary. In that case, if the hill from whence it issues, be of considerable extent, whether of great height or otherwise, the water will flow throughout the greatest part of the year with a stream pretty equable; and if the bed of sand be moderately deep, that water will never be forced so far upwards among the sand, as to prove hurtful to vegetation; and it will form a field of a dry sandy soil.

But if some grounds rise above this to a considerable height, which are so formed as to throw the water that runs from them, during violent rains, into places where it can sink freely into the bed of sand, it will then force forward a much larger stream of water towards A, than at other times; and, of course, that water will rise to a greater height among the sand than before (and the same phenomena will occur, if the surface-water, during rains, be brought from a great distance, till it reaches the upper part of the bed of sand, towards B, where it will be absorbed). In that case, the under part of the bed of sand,

sand, towards A, where it is not so deep as above, will become very damp, while that above will remain dry. When this case occurs, the cure is, to dig a ditch across the field, at the place where the wet first begins to show itself during the wettest season, quite through the bed of sand, till it penetrates into the clay (as in every case of this sort) the open part of which must be of such a size as to carry off the whole of the water it intercepts in its course. In these circumstances, however, it will be well to observe, in the first place, whether the bed of sand be not interrupted at its lower end, by a bed of some more impervious matter, which, by preventing the water from flowing off as fast as it comes to it, forces it up towards the surface; for, in that case, it will be, in general, much less expensive to open a ditch through the impervious stratum, that interrupts the stratum of sand in its bed, and running that ditch up the hill, till it comes forward to the sand; and to make it of a sufficient depth, which will give free vent to the water, than to drain the field in any other way.

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This is a case that ought to be carefully adverted to; for no soil that I know, is more worthless than a damp sand.

In all the cases above specified, it is very obvious that no sort of benefit could possibly be derived from the practice of tapping.

Nor, unless in the very last-named peculiarity of the case, could drains, if carried in a direction *up the hill*, afford any efficacious remedy, even if they were made at a very small distance from each other; for the water would follow its course down hill between the drains, nearly as before the drains were made.

The doctrine of wells being so intimately connected with that of draining, I shall hold myself excused for making some remarks on that subject, where they are incidentally suggested by the circumstances treated.

Let it be observed, then, that in cases of the sort now under discussion, if the water were supposed to have a free issue at A, were a well sunk into the bed of sand, at B, no water could be there permanently found until it penetrated quite through the stratum

stratum of sand, and went to some depth into the bed of clay below it. In this case, the water could never rise in the well much higher than the line *b c*, Fig. 27, because, whenever it rose as high as the porous sand, it would flow along through it, till it made its escape below; and if the bed of clay extended backwards underground a great way, and at a great depth below the surface, so as to form an abundant and never-ceasing stream under the bed of sand at B, it must follow, that the well will continue constantly at the same height, exactly like a stone basin at a fountain, into which a pipe of water constantly flows, so as to keep it running over. This happened to be exactly the case with a well of water that was at my door in the neighbourhood of Leith. A bed of sand reached from the surface, to the depth of twelve feet, nearly; the well had been sunk about three feet in the clay upon which the sand rested, and the stream of water was so abundant as to keep that part of the well which was sunk in the clay constantly full, so that it was scarcely ever known either to sink or to
rise

rise six inches above or below its ordinary stream.

But if the stream that runs below the bed of sand be small, and the draught of water from the well, at particular times, be uncommonly large, the surface of the water in the well will of course be made to sink : it may be indeed quite drained of water at times, so as to require to be left for a while till it shall fill again. This may be occasionally a very serious inconvenience, and ought to be guarded against by enlarging the reservoir, which may be effected either by widening the diameter of the well, or by sinking it to a greater depth in the clay, or both. Hence, it appears, that *in cases of this sort*, a very *wide* well ought always to be made. Other cases will come to be noticed in the course of this Work, in which the *straitest* well that can be made, would supply a quantity of water as abundant as those that are wider.

Nor would the phenomena here described be in the least varied if the well, instead of being dug in the sand immediately below the vegetable mould, as at

B, should be first sunk through a considerable thickness of some other strata, as at C. The depth of the well only would be greater, and all other circumstances the same.

Please also observe, that if there be an opening at A, so as to allow the water to issue freely from the surface of the bed of clay, the body of sand above it will be a firm solid body; and in this case, if houses are founded upon that sand, with the precaution of putting planks of wood, or large flat stones, as a foundation for the walls, these buildings will remain as stable for ages, as if they had been founded on a rock. This is precisely the case with the town of Leith, the sea-port of Edinburgh, the houses of which all stand upon a bed of sand from eight to twelve feet deep; and there are houses there of more than a hundred years old, the walls of which are now standing as true to the plumb, as if they had been built but yesterday. But if, instead of having had a free issue at A, the bed of sand had been there interrupted as at A, Fig. 21, the water, in this case, would have been regorged
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back among the sands, and, perhaps, would have formed a bed of that unmanageable body, which architects so much and so deservedly dread, under the name of *quick-sands* * ; and which, when it comes in the way in digging wells, or other subterranean operations, presents obstructions that can be only with great difficulty surmounted.

The obvious cure of this disease (quick-sands) when it occurs, is to search for the means of opening an outlet by which the water may be suffered to run off.—This,

* An apology may, by some, be judged necessary, for here incidentally mentioning *quick-sands*, as a thing that may, perhaps, be thought in some measure foreign to the subject. As I aim at giving clear and discriminative ideas on every case that may occur in the practice of draining, and as this case may, and certainly does, sometimes occur; it does not seem to be foreign from the object of this disquisition: and it appears to be the more necessary at present, as I do not know that any satisfactory explanation has ever yet been given to the public, of the circumstances which give rise to the phenomena of quick-sands; and of course, no rational method of removing this distressful malady has ever yet been attempted. A very able engineer, some years ago, from a total inability of forming clear ideas on this head, made some very ridiculous estimates of improvements proposed at Leith; which he never could have done had he been better informed on this head.

where

where the quicksand is situated above the level of the sea, or some adjoining plain, may in many cases be effected at very little expence; if due attention be bestowed upon the position and natural dip of the strata, which may be discovered by various means besides boring.

But there are cases, particularly where the quicksand is produced by a cavity like a basin scooped out of the entire bottom, so as to contain water to a considerable depth, which in some particular situations may be deemed incurable.

It deserves also to be remarked, as a circumstance necessarily accompanying springs of this kind, that the digging wells in a higher position, as at C or B, will not sensibly diminish the quantity of water that flows over the lower surface of the clay towards A; for, as the well, as soon as it is filled, must overflow; that will intercept not one drop more water than what is drawn up out of it. Were it even possible to pump the water from the well, as fast as it falls into it, so as never to allow one drop to run over, the case would not be much altered; because no more water could be
thus

thus intercepted than that which would have flowed into the mouth of the well in its descent, so that every drop that would pass the mouth of the well, on either side, would flow forward to the lower situation, as if no well had ever been made. Hence we see that springs of this sort can never be intercepted by wells, or sensibly affected by other wells placed either higher or lower than them. - Wherever this case exists, water will be found nearly in equal abundance, whatever the relative situation of the well may be in respect to others; nothing but an *uninterrupted trench*, of a size sufficient to intercept *all* the water as it flowed, and to carry it off, could dry up the springs below it.

We may also observe that if the bed of sand be of great extent, if it be at last supported by a bed of clay or other impervious matter, water will undoubtedly be there found, whatever may be the depth of the bed of sand above it, if a well be dug through it; for, as the water that falls in showers upon the earth's surface necessarily sinks through that pervious stratum, it is soon beyond the reach of the sun, so as not
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to be evaporated, and must sink downwards till it meets with an impervious stratum, so that there can be no doubt but that under the immeasurable deserts of Lybia, there must be water in abundance, to supply any number of persons, were wells there sunk to the requisite depth: Nor is that depth perhaps, in many cases, nearly so great as has been in general apprehended.

I may here also be permitted to observe, that many instances occur of streams of water flowing over the surface of beds of sand of the kind here described, without sinking into these sands. Sometimes the surface-sand is even rendered hurtfully wet by water stagnating upon it, while springs of the sort above described, are freely running below. This phenomenon is occasioned by a natural process, similar to that which is now adopted for rendering canals retentive, called *puddling*. When this happens to be the case, the stagnating surface-water may be let off merely by digging a hole till it penetrates the crust which has been rendered retentive by means of the natural *puddling* process, and till it reaches the unmixed sand, through which it will
sink

sink with the greatest facility. I have often, in this manner, opened up a hole, in the space of half a minute, in such situations, which has swallowed up at once a stream that flowed into it, which was so abundant, that, with a moderate fall, it might have turned a mill; and which if not thus let off, might have produced very extensive mischief, by flowing over the surface of the ground. In such cases, the small opening thus made, in a short while, becomes *puddled* so as to be retentive, and thus closes up, so that a fresh hole must be opened, if the stream continues long to flow, where much mud is carried with it.

Let us again suppose that A B (Fig. 27) represents a stratum of sand, gravel, stone, or other pervious matter, lying between two beds of clay, E F and C D, which unite at the point A, where the stratum of sand is interrupted. In that case, the water which flows from B towards A, when it reaches that point, will be pent in, as if in a horn, so as to have all the vacuities filled with water till it rises to B, or some other point where it can be permitted to flow off. If the upper bed of clay, E F, be of a sufficient

cient thickness and tenacity to resist the whole pressure of the water below, the surface soil will be in no manner incommoded by it; but if that bed of clay be not very thick, the water will be squeezed upwards through any small cracks that may occur, producing spouting-ground or bogs on the surface, as described in the First Part of this Essay. In a case of this sort, it is very plain, that no surface-drains could afford any adequate relief—for while the water is suffered to remain in the reservoir below, no operation performed upon the surface can prevent the water from being pushed upwards, through the natural channels it will find for itself. In this case, tapping is the only remedy, which, by giving free issue to the water through an opening made for that purpose, in the upper bed of clay, diminishes the altitude of the confined water within, and, of course, removes the pressure from below; which, as it was the sole cause of the malady, a radical cure must thus be effected.—The only question, then, that now requires to be decided, is, “in what manner ought we to

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proceed,

proceed, so as to effect a cure, *at the least expence possible to the employer?*"

Let us suppose that the whole surface between G and L is hurt by superfluous water—but that towards L, the ground becomes gradually sounder, the surface near L being only wet during rainy weather. In this case, should a ditch be drawn along the face of the hill at L, in a direction nearly horizontal, allowing only a sufficient declivity to carry off the water in it, it is plain that this ditch, unless carried to a very great depth, at an enormous expence, could do little or no service.—And if it were here tapped, by boring a hole through the bed of clay, as is represented by the line at L, the relief it would afford would be very inconsiderable; as it could, at the utmost, give vent to the water only until it sunk to the level L K, so that all the parts of the field below L would be little better than before.

Should another ditch be opened in the same manner, lower down the declivity, as at M, and should it be there also tapped, the water would then be allowed to subside

to

to the level-line M N ; and all the ground between L and M would be effectually drained. In this case, we have derived some benefit from our operations, though at an expence greatly more than was necessary; for if the operations at M had been first made, the drain would have been as complete as it now is, though nothing had been done above—All that has been expended on the operations at L, then, would be money thrown away to no purpose whatever.

Still, however, the ground between M and G is in want of draining, and we must now go lower down: Suppose we should go at once to G, and there make a similar ditch and tapping; in that case, the water would be made to sink to the level G H, and the whole field effectually drained at once. It is scarcely necessary for me now to remark, that had this been done at the first, the field would have been as effectually drained, without any of the operations above. I state these particulars, here, by way of illustration, as a caveat which ought not to be neglected—for I have often observed, that men who attempt to drain land, without understanding the principles of the

art, have a great propensity to follow the mode of conducting their operations above described, who, if not restrained, may, in many cases, subject their employers to a most exorbitant and unnecessary expence, even where they do at last succeed in the purpose intended.

Observe, however, that in this particular case, had the tapping been made lower down, as at I, no good whatever could have been derived from the operation at that place. As this case but rarely occurs, yet from this illustration the use of the previous boring for exploratory purposes is made very manifest.

It has been shown in the First Part of this Essay, in what cases a ditch opened upon the *upper* edge of the wet ground is required for effecting a complete drainage—to which the reader is referred.

The surest rule, I can at present think of, for distinguishing the cases, where this mode of proceeding (that is, by means of a ditch carried across the declivity, above the highest part of the wet ground) will be useful, from those in which it must prove nugatory, is this: Wherever the water that is to be carried off, can be made to find access

into the ditch only by means of *tapping*, there the opening of a deep ditch, in this situation, may be declared nugatory—and wherever a ditch in that situation can prove radically useful in draining the lower grounds, there tapping can prove of little or no service whatever.

Another economical consideration, that ought never to be lost sight of, is, that in the mode of draining by means of tapping, ditches of a *great depth* can never be required, so that if deep ditches are ever made where this mode of draining is adopted, it must be accounted a mere *useless expenditure of money*. The only use of the drain, where tapping is beneficial, is not to *intercept*, but merely to *carry off* the water.—And if the drain be of a size just sufficient to carry off all the water that rises through tap-holes, nothing more can be required. In general, a ditch of two feet deep will effect this purpose as well as if it were twenty—but the expence of making it will be very different.—As there are men, however, who value things merely in proportion to the money these things cost them—it deserves the consideration of *practical* drainers,

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whether

whether it would be *prudent* in them, to lay aside expensive and stupendous operations, which often strike the imagination of men, and thus make the improvements which seem to require this expensive apparatus be attended to, when trifling operations, though equally efficacious, would be neglected and despised? Let Noblemen, and others of high rank, then, be indulged in these expensive and showy operations—the country is benefitted by them—But if ever practical farmers should engage in undertakings of this sort, it is proper they should advert to the article expence, as of the first importance.

In all cases of this sort, now under consideration, where the current of water that flows in the pervious stratum is not very great, and where that stratum continues without interruption, and undiminished in size to the bottom, the drainage will be completely effected, by tapping in the *lowest* part of the field only.—But where the depth of the pervious stratum is diminished considerably, as at A (Fig. 28) or, what comes to the same thing, where it meets with casual though not total interruptions—
and

and if the current of water should be considerable, it may happen that a small part of the water only (viz. less than flows into this reservoir from above) can reach the point A, and as no more water than reaches that point can be made to rise through the holes there made, it must in this case happen, that the drainage will not be completely effected by the opening at A. In that case, after trial has been made, and time allowed to see whether the drainage is complete or not—should it then be found necessary, it will be proper to go higher up, as to E, and there open some fresh taps; and should that be still found inadequate for the purpose intended, go still higher, to D, and so on, higher and higher, till it be finished.

In cases of this sort (which are rare) it will be proper always to *begin* at the lower extremity—and if water rises at all where tapped, be sure to make the tapplings sufficiently numerous to allow the whole of the water that comes to the place where they are made to issue freely. You will easily know when these openings are sufficient for the purpose—for, in that case, after a

short while, the water will not rush up through them with great violence, but will flow off gently, without any appearance of boiling up.—If that appearance of boiling does not subside, it is a sure indication that a greater number of tap-holes are wanted—and they ought to be made. If this be first done, and you find that even in the wettest season, the water rises gently through the tap-holes, you may then, in general, be satisfied that no opening above will be wanted; but in order that no doubt may remain on this head, you may easily satisfy yourself, at a very small expence, whether any openings above are wanted, merely by putting down a bore by your tapping implement, at some little distance above the former opening. If the water, in that case, rises in the tap-hole you have just made, it is a sure indication that openings at that place are wanted; and, therefore, a drain should be there opened, and taps sunk in it, as before—but if during the rainy season no water rises through the tap-hole, it is an indication equally clear that no openings are there wanted. In this manner, by boring only, without making drains, until
you

you see whether they are necessary or not, you may proceed upwards, till you ascertain the facts with precision.—By means of the boring instrument, also, you may ascertain with precision the nature of the strata, and their limits, where they are broken or interrupted, so as to be able to know with certainty, before you commence your operations of expence, in what manner you ought to proceed. General ideas, collected from external appearances, may serve very well to direct in plain cases, or to indicate where anomalous cases occur; but in difficult cases, particularly where the strata are broken and jumbled together, external indications can only produce guesswork. The borer only can be relied on.

It will not be expected that I should here enter upon an enumeration of anomalous cases; for these may be so much varied, as that a complete volume could give but a partial statement of them. Fortunately, cases of this sort are few, and of comparatively small extent. There are particular cases where the strata have been much deranged, more especially where rocks intervene, in which the expence of draining

draining would be much more than could be repaid by the subject. But these bear such a small proportion to the fields that could be drained with profit, as scarcely to deserve to be named in a treatise which relates to practical cases alone.

I have already mentioned some cases that relate to digging for wells. The following cases are of a different class :

Probably, some of my readers may recollect having read in the Philosophical Transactions, some years ago, an account of the phenomena that occurred in sinking a well at Sheerness, near the mouth of the river Thames ; some of which phenomena were deemed, by many persons, rather of a wonderful kind. They were as follows : That fort is placed upon a neck of land, very little elevated above the surface of the sea. In digging the well, they passed through a bed of solid clay, to the depth of fathoms, without finding water of any kind ; but at that depth, they found a spring of *salt* water ; which, not being irresistibly abundant, they found themselves enabled to wall it out. This being done, they then sunk, once more, through

through the same bed of clay, for fathoms more. Here they found another spring of *salt* water, as before ; which, having walled out also, they continued to dig through the same bed of clay, for 300 feet more ; at the bottom of which they found a bed of gravel, from which issued a copious stream of fresh water, which soon filled the well within five feet of the top, at which height nearly it has remained ever since.

Wonderful as this may seem, at first sight, to some persons ; it will appear, in no respect, inexplicable to those who have adverted to the phenomena that occur in the tapping for springs, so fully explained in the foregoing parts of this Essay. Let A, Fig. 29, represent the fort ; B the sea ; CDE a bed of solid clay, stretching out beneath the sea, and backward into the land to an indefinite distance. FGH represents a stratum of gravel, or other pervious matter, lying upon another bed of clay, IKL. Under these circumstances, the stratum FGH, having no opening at the lower end, must form a reservoir of water, which must rise upwards towards F, till

F, till it finds some opening near the surface of the ground, through which it can make its escape. This being the state of things, it is very obvious, that as soon as the well MN reaches the bed of gravel N, the water contained there must be forced to ascend till it reaches as high as the water contained in the internal reservoir within the mountain. If the spring affords more water than is taken from the well, it will continue always at that height; so that the water can only sink in the top of the well, when more is drawn from it than the spring can supply in a given time.

With regard to the salt-water springs, the diagram will explain that phenomenon, at first sight. At P and Q, two fissures, occasioned, perhaps, by the working of some animal, or other unknown cause, have penetrated the bed of clay, from the edge next the sea, to some distance as far inward, at least, as the pipe of the well, through which, of course, salt-water would flow into the well as soon as they were opened.

Another phenomenon of a similar kind,
but

Fig. 25



Fig. 26

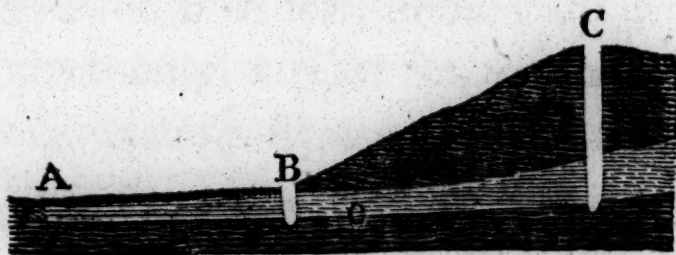


Fig. 27

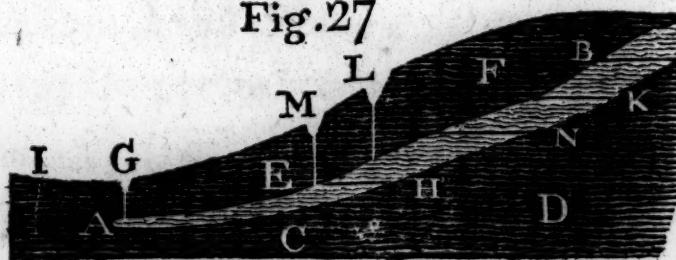


Fig. 28





but less complicated, because divested of the circumstance of the salt-water, is mentioned by Dr. Darwin, of Derby : A well was sunk in that town (which lies in a bottom, surrounded with many hills). After digging through a bed of clay for some considerable depth, they found an abundant spring of fresh water, which, as in most cases of this sort, rushed up with great impetuosity, and soon filled the well to the top, where it flowed over in a pretty copious stream. Dr. Darwin seeing this, and conceiving that it might descend through a subterraneous funnel, that rose to a greater height than the houses of the town, easily perceived, that if he could raise the sides of the well to a sufficient height, making them, at the same time, strong enough to bear the pressure of the water, he might get it thus conveyed to the highest floors of his house. This he actually effected, and enjoys, I suppose, the benefit of his ingenuity, till the present moment.

I do not hear that Dr. Darwin has thought of extending this discovery to any other use ; but if an abundant spring
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should be thus discovered, which could be forced, without the power of machinery, to rise to a great height, it might, doubtless, in a mountainous country, where phenomena of this sort must chiefly occur, be employed to great advantage as a power for turning machinery. To illustrate this subject, let Fig. 30 represent the section of a hill, containing an internal stratum of pervious matter, inclosed between two solid beds of clay; in other words, an internal reservoir, filled with water. If this reservoir should be discovered, by means of boring, or otherwise, as at AB, and it was found that the water would rise to the height of A; then, by digging a shaft, of sufficient dimensions, and building the sides of it as you proceed, till it reaches the gravel at A, then the water would rise and flow over at A, till the internal surface of the water sunk to the level of the line AC; after which, the whole water that the spring supplies would continue to flow over at A, and form a perennial stream, perhaps extremely abundant; the uses of which, in such a situation, are very obvious.

vious. St. Winnifred's spring, near Holywell, Flintshire, which is so abundant as to turn nine mills, is a natural burst of the same sort with that I now describe (for it is not a great while since it first appeared). But were the spring much smaller than it is, the great height of fall that might thus be obtained, would give it a commanding power for turning machinery.

Should an opening of the kind here mentioned be ever made, it is plain that its effects must be sensibly felt in some other place; exceedingly so, indeed, if the stream be abundant; for a reservoir of the kind here supposed, must, of necessity, have an outlet somewhere, for discharging its waters; and, as in the case here supposed, that outlet must be on a higher level than the other, it could not fail that when this last was opened up, the other must have failed, so that a stream which issued perhaps from an opposite side of the hill, possibly, at many miles distance, would be entirely dried up, and another formed, that might take a direction to the sea totally different. These phenomena, when thus explained, are as natural as that the sun

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should

should give light when it shines; and can excite wonder in the mind of those only, who have never adverted to the physical conformation of our globe. Indeed, the *borer* has been but too little used, in consequence of which, many facts that might have been highly beneficial to man, have totally escaped his notice. I shall beg leave to specify a few, with a view to direct the attention of the public to this interesting subject :

At Halle, in Germany, a spring of salt-water was discovered, many years ago, which when manufactured into salt, affords a great revenue to the King of Prussia, in whose dominions it is placed. Halle being situated very near to the confines of Saxony, the Elector was in the practice of purchasing brine from thence, which he carried into his own dominions, and there converted it into salt, for the use of his subjects. As the carriage of this brine was attended with a considerable expence, the Elector often expressed an earnest wish, that a spring of salt-water could be found in his own dominions. This turned the attention of his people to this subject,

ject, and at last an unlettered peasant, in the neighbourhood of Leipfig, presented himself at court, and made offer, at the risk of his head, to find salt-water at a place he should indicate, if the Elector would be at the expence of digging for it.—It was some time before this poor man could adduce such arguments as to satisfy the Electoral council, that there was such a probability of success, as to authorize them to risk the experiment; but at length he prevailed. The work was begun at a place called Durlinberg about 15 miles distant from Halle. For some time nothing extraordinary appeared, but at length they came to a spring—of fresh-water only.—This did not discourage the peasant, who ordered them still to go on. With some difficulty he effected this point; but as the water from that spring incommoded them a good deal, it excited a murmur against the poor man. After digging somewhat farther, they came to a second fresh-water spring, which threw the undertakers into such a rage, that they would not listen to the poor man, who urged him still to proceed; but, on the contrary,

the man seeing them in such bad humour at being frustrated, after having expended so much money, he began to dread some mischief to himself, and secretly withdrew himself from the electoral dominions. Soon after this event, the king of Prussia overran Saxony, during the seven years' war, and the operations at this well were forgotten. When peace was afterwards restored, and the minds of men a little cooled, the peasant ventured to return.—His mind was still set upon completing his enterprize; and he spoke with so much firmness on the head, and adduced such cogent arguments in favour of his opinion, as prevailed upon the court a second time to begin the work; he having the precaution before they began to tell them, that as the spring was probably at a considerable depth beyond what they had as yet reached, they must be determined not to be soon discouraged. They again went on, and, as he had said, they did indeed, when at a very considerable depth, open up a spring of *salt-water*; which rushed into the well with such impetuosity, as soon filled it to the top, over which it flowed,

flowed, for some time, in such abundance, as to occasion considerable damage; but this violent burst subsiding by degrees, they began to erect salt-works, which continue to be worked till this day. This is one practical proof, at least, of the benefit that society may derive from the study I here wish to recommend. Nor have I a doubt, but if it shall be properly attended to, many other benefits, equal to the above, may be derived from it.

It is well known, that at Newcastle upon Tyne, and at Bo-ness, in Scotland, coals are dug at a great depth below the level of the sea; and even below the bottom, and immediately underneath it.—As no salt-water is discovered in these coal-mines, it affords the most demonstrative evidence, that the bed of clay that lies above the coal is perfectly impervious by water; of course, the water which is found in the coal-mines, and which occasions much expence to discharge it, can get access into it in no other way than by descending along the tract of the coal-seam, from the place where it approaches towards the surface of the

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ground,

ground, exactly in the same manner that springs are accumulated in other pervious strata. Hence it must happen, that if this stream of water should be intercepted in its course, and there carried off to the surface of the ground, no water could get into the mine; so that all the coals below that intersection would be laid quite dry, by a process in every respect analogous to that of intercepting the springs, described in page 72, and with an effect *nearly* equally beneficial. I say *nearly* in this case, because no operation of this sort could *entirely* remove the water from the coal-mine; for as there must be some fissures among the coals, through which the water has originally flowed, so these fissures, in a situation like that described, must be entirely filled with water, which would of course run in the pit, after the coals are taken out, but this would be such a trifling matter, as not to deserve any notice.

Let A B (Fig. 31) represent a seam of coals, rising at A towards the surface, and at B dipping beneath the sea. Let it be supposed, that at C it has attained such an elevation

elevation as to be above the level of some vale or rill of water, and that, of course, a level driven from the surface at that height, till it reached the coal, might serve the purpose of carrying off all the water that should fall into it. In that case, were the stratum of coal there pierced through, as at C, supposing that to be the only stratum permeable by water, it would follow, that all the water which had formerly been conveyed through that stratum, would be there intercepted, and carried clear off to the surface of the ground ; and that, of course, all the coal that lies below it, would be, from that moment, freed from any additional accession of water. In this case, the level would not only serve to free the *upper* part of the coal-mine from hurtful water, which is all the benefit that has hitherto been aimed at in works of this nature ; but the *under* part of the mine would be also benefitted by it nearly to an equal degree.

Where the strata were so disposed, as by varying the direction of the drain, it could be pushed forward, without falling below the level, till it had cut through

the bed of coal for its *whole breadth*, the cure would be quite complete. This case may probably sometimes occur ; but I am as yet too little acquainted with the actual circumstances of this nature, that occur in practice, to be able to say whether it would be very rare, or the reverse. Indeed, as the subject has never been as yet considered under this point of view, I think there is reason to suspect it is not known by any human being. It is certain, that much benefit is yet to be derived from a more thorough investigation of this intricate, though very interesting subject ; and every hint that tends to elucidate it in any degree, deserves to be attended to.

It would be impossible to enumerate all the benefits that might be derived from the practice of *tapping*, judiciously applied, were the nature of the strata, and the physical conformation of the earth, sufficiently adverted to.—Were I even to attempt to give examples of *possible* cases, by way of illustration, it would be deemed hypothetical and absurd. Yet it must certainly be deemed more absurd, by every rational person,

person, to observe, that we allow natural phenomena, which ought to suggest practical lessons of wisdom to the attentive observer, to afford only matter of stupid admiration. We see, in some places, rivers sinking into gulfs in the earth, and disappearing. In other places, we see subterraneous rivers issuing from caverns, while other rivers are meandering on the earth's surface above them.—We see lakes of great extent, surrounded by mountains, that cannot be drained, according to the ordinary mode of procedure.—Mines are deserted because the water cannot be carried off from them, on account of the immense length of a *level*, that would be required to be driven in order to drain them. All these things we see as isolated facts, that cannot be in any way accounted for, or connected together. Yet that they may, on some occasions, be *so* connected, as to prove highly beneficial to man, I shall venture to show, even at the risk of being accounted visionary.

We have seen, from the fact respecting the well at Tilbury Fort, and the working of coals under the sea, at Newcastle
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and Bo-nefs, that water may be preserved in a bafon of immense extent, though bounded by a cruft of impervious matter, which is of no great depth. Thefe cafes alfo prove, that strata of pervious matter may lie under thefe ; of courfe, many oozing fstreams, or even fubterraneous rivers, may run, at no great depth, beneath lakes, or rich mines that are drowned in water ; precisely in the fame way that we have feen (page 64) that a fstream of water may be carried along the furface of a bed of fand, at the bottom of which runs a current of water fufficient to fupply innumerable wells abundantly with water ; and that this furface-water, if the cruft be once broken, immediately finks into the fand, and totally difappears. Should any accidental convulfion of nature then break the cruft that fupports the lake, fo as to permit it to find its way into thofe cavities below it, it would, through thefe iffues, find accefs to the fea, and the lake would be effectually drained ; fo as to become, in time, like the kingdom of Cachemire, a fertile vale, though every where furrounded with hills, through which no outlet could be had,

had.—Might not the same effect be produced by the ingenuity of man, were he at pains to exert his faculties in cases of this sort? An earthquake, it is supposed, opened a passage through the mountains of Cachemire, by which the water issued, so as to drain that immense lake, and through which the river which traverses that bottom still flows. An enterprising individual, who possessed a small lake on his property, near Glasgow, effected a drainage, in imitation of this, by digging a level passage through a surrounding hill, through which the water flowed off, and which still operates as a drain. Many cases may occur, in which a similar drainage might be effected, at a much smaller expence, by sinking a pit downwards, through which the water might issue by subterraneous passages; and in the same way, at times, it may doubtless happen, that water might be let off from mines at a very small expence, compared with that which the driving a level might have cost. Wherever operations of this sort are in contemplation, therefore, it behoves the owners to advert to these peculiarities, and

and to be at more pains to acquire an accurate knowledge of the subjacent strata, in hilly districts especially, by means of accurate observations, assisted by boring, than has hitherto been done. For in this way, doubtless, very great improvements may be made at a trifling expence.

With a view to illustrate this branch of the subject still more clearly, I have added a diagram (Fig. 32) which is intended to represent a section of a hilly district, in which A B represents a lake of indefinite magnitude, every where surrounded with hills, which raises the water to its present level, where it finds an outlet at A, and flows from thence in a valley between the hills, till after running thus many miles, if you please, it precipitates itself over the rock C.

At the bottom of this hill, C, issues a considerable stream of water from a large cavern, like one of the same kind near Matlock, in Derbyshire. This subterraneous river, we may suppose, indeed, we may be assured, flows from a great distance backward. If it be of a large size, it must have come many miles, indeed,

flowing all the time through open rocks, or other pervious strata, in a direction nearly similar to that marked DE, which may be expected, in general, to lie at a depth rather above than below the level of the opening from whence it issues. Under these circumstances, it is plain, that if an opening were made in the bottom of the lake, as at G, the water would sink directly from the lake, into the channel of the subterranean river, and if that opening were large enough, the whole water of the lake would sink through it, and it must, of course, be effectually drained.

Again, let us suppose that F represents a mine of lead, or other metal, which has been there discovered, but which is so drowned in water that it cannot be worked with profit. According to the usual practice, the owner of that mine has no other way of draining off this water, but by taking the depth of the bottom of the mine, and surveying the ground around it, so as to be able to mark the nearest place on the hill side that is on a level with the bottom of his mine, and from thence he derives a level C F till he reaches the mine. In many situations,

situations, that level may require to be driven several miles in length, before it can reach the mine, the expence of which can never be repaid, and therefore the mine must be abandoned for ever.—And where it is even found that the mine is so rich as to afford the expence—yet the time that must be expended on this operation (where one or two men only can be permitted to work at once) is a most discouraging circumstance, as five, ten, or even twenty years may be expended before it can be completed.—But, in the situation here described, it is evident from inspection, that if a perforation had been made right downwards, from F, it would soon have reached the subterranean river, and thus have freed the mine from the extraneous water, at an expence inconceivably small.

Not only could the hurtful water be thus easily abstracted, but other uses could be made of this subterranean drain, that would prove highly beneficial to the undertaker.—If a small stream of water, for example, could be brought to the mouth of the pit, it could be employed, by means of a chain and buckets, to raise up the whole of the ore to the surface, at next to no expence to the undertakers ;

undertakers ; or, after space sufficient for that purpose was once worked out, it could be made to drive stampers below, for stamping and washing the ore, there, before it be brought out of the mine, and for other uses.

Nor let it be thought that these are chimerical or impracticable notions : There are many situations, already known, upon the earth's surface, where these operations might be undertaken not with a *probability* only, but with a *certainty* of success. The river Guadiana, in Spain, sinks at one place into the earth, and after running under ground for several leagues, rises again to the surface. —Now as no holes have ever been discovered in the bowels of the earth, resembling a bored pipe, or mole-rut—but the openings there, through which water flows, are universally found to consist of porous strata, which spread out in breadth to a great extent—there is a moral certainty that there must lie beneath the surface of the ground, every where between the place where the river sinks, and where it rises, a large stratum of pervious matter, which probably stretches to a great extent on either side,
and

and that, of course, if any mines were discovered in that tract, they could, with *certainty*, be drained in the manner here proposed.

It is also known, that in the hill called Ingleborough, in Yorkshire, there are many openings, called there *Swallows*, into which rivulets precipitate themselves, and are lost. Where these streams re-appear, I do not at present know; but wherever it is, there can be no doubt that all the tract between the one place and the other must be hollow, and of course, could readily admit of the mode of draining here proposed.

It is also known, that in Derbyshire, the river Dove, I think (I quote from memory) sinks into the earth, and at a considerable distance rises again.—Subterraneous rivers are known to issue, also, at other parts in Derbyshire, and in Devonshire, in Denbeighshire, and several other places, I have not taken notice of; all of which give sufficient indications of a similar general organization, to render it next to certain, that in those regions, operations of the sort here recommended, would prove successful. The same conclusion may, in general, be
inferred

inferred in all the mountainous regions, where very copious springs burst forth, whose waters are little affected by the temperature of the season, being very cold in summer, and warm in winter; for this circumstance always indicates, that they have come from a considerable distance within the bowels of the earth—Other indicative circumstances might be pointed out, which I have not time to enumerate.

Having now, as I hope, *proved* in a satisfactory manner, that the mode of draining here recommended is a very practicable process, I shall add nothing farther to the length of this Essay, than to give a few hints respecting the manner in which that operation may be the most easily effected.

On this head, it will be very obvious, that where much water is in the place to be drained, it would be, in all cases, a difficult matter, in many cases impossible, to sink a pit directly downwards, immediately from these reservoirs, by digging. In such situations, this operation ought to be effected by *boring*. When, by means of a borer, the subterraneous vacuum has been

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once

once attained, a certain judgment can be formed of the expence of the future operations. The width of a bore that can thus be made is, indeed, but small; but much water will be let off through a very small bore, under the circumstances here indicated, because of the altitude from which it must descend. If the stratum through which the bore passes, shall chance to be clay its whole length, the hole would quickly become of a sufficient width to give passage to the whole water. But if it consist of harder materials, more bores must be made; and these, if made in a circle, of no great diameter, pretty near to each other, would give the water a chance, by its great force in rushing through, to break down, by degrees, the whole of the circular solid, and leave a cavity in its stead; at any rate, there are few mines which have so much water as could not be let off by a few such bores alone.

With regard to the drainage of lakes; if these are of great extent, it will become a matter of greater difficulty and expence;

AND SWAMPY GROUNDS. 163

pence ; but as the profit will be great, in proportion to the extent, that circumstance will, no doubt, be taken into the account. In all cases, the ascertaining whether the thing be practicable or not, can be done at a trifling charge ; for a single exploratory bore will ascertain not only the depth to which it must be carried, before it reaches the pervious stratum, but also the nature of the materials through which it has to pass ; and, consequently will give room for a pretty accurate estimate to be made of the expence.

In making this exploratory bore, one circumstance must be particularly adverted to ; for as it will be necessary to make that bore, if possible, in the deepest part of the lake, it will be a matter of some difficulty to ascertain whether the small bore, under these circumstances, allows water to flow through it or not ? This point, however, may be ascertained by means of the boring irons alone ; for if the mouth-piece be thicker than the rod, it will no sooner reach the pervious stratum below, than the water, rushing downward with great impetuosity around the

M 2

rod,

rod, will prevent the possibility of drawing up the mouth-piece any more. To guard against this circumstance, which is to be expected, the mouth-piece ought to be so fixed on, as that by turning the rods the reverse way, it may be unscrewed, so as to be detached from the rods entirely, which may then be drawn up without it. Of course, all the joinings of the rods must be so fixed, as not to be loosened by that reversed motion.

It will not, however, be expected, that where a large river passes through a lake, like the Rhone through the Lake of Geneva, or the Rhine through that of Constance; or even much smaller streams than either of these, could, by a process of the kind here hinted at, be ever swallowed up. There are few subterraneous strata, we are to suppose, so large as to admit of carrying off a current of such magnitude. But if that should be found to be the case, the passage for the river into that subterraneous stratum should be made, not in the bottom of the lake, by boring, but at the edge of it, near where the river falls into the lake; and this passage may be dug,

AND SWAMPY GROUNDS. 165

dug, by hand, of a sufficient width to swallow up the river when flooded, and then the river may be led into it, so as never to be allowed to reach the lake at all. But this, for the reason assigned, can seldom be practicable with respect to large rivers; and in regard to smaller rills, that feed lakes, in general, it will be cheaper (unless where the under-stratum is clay, and of very little depth) in most situations, to make a water-course all round the lake, nearly in a horizontal position (with a gentle slope only towards the outlet) to intercept all the rills, and the water that falls from higher ground, and carry it clear off, without allowing it to descend into the bottom. In this way, no other water will require to be let off through the bottom hole, than that which arises from springs within the lake itself, which probably are, in many cases, not numerous.

It is to be hoped the candid reader will receive these hints with indulgence, they being intended to throw some light upon a subject of great national importance, which, if it be understood by any one, has

never hitherto been explained with the precision which is necessary to render it intelligible to ordinary readers, for whose use these directions have been made out. On a subject of this nature, I have found, by experience, that it is by no means enough briefly to explain the principles on which a successful practice may be rationally grounded; for it is only a few persons from among the great numbers who may be benefitted by it, who will be able or willing to make the practical deductions that a philosophical mind would see are obvious from the premises. To render a practical treatise generally useful, it is necessary to enter upon particulars in detail, and give special illustrations which philosophical hypercriticism might pronounce to be unnecessary. In the Additions now made, perhaps, little can be said to be new; yet I am inclined to hope, that in consequence of these additional illustrations, the Treatise will be rendered more generally useful than it hitherto has been. I shall only add, that the latter part of these illustrations, especially, were written under circumstances rather unfavourable

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able for precision, and therefore claim a share of indulgence from the critic, particularly in what regards their form. As to the matter, no indulgence is requested; for if any thing essential be erroneous, it is of importance that it should be corrected.

CORRECTIONS AND ADDITIONS.

WHEN the above was written, I had no opportunity of consulting the Philosophical Transactions, and was therefore obliged to quote from memory, the fact respecting the well at Sheerness; and the plate was engraved on the idea there expressed. I have since seen the 74th volume of the Transactions, in which, that fact is recorded, and find it only differs from the account given above in one particular, viz. that the uppermost stratum, to the depth of 30 feet, consisted wholly of sand, and that all the water which was found in that part, was salt to the taste; in every other respect, it was exactly as above stated. This circumstance requires no

M 4 alteration

alteration to be made, as the illustration would be the same. In a few particulars, of no moment, the case respecting Dr. Darwin's well, is also a little different; but, as this illustration is perfectly the same, it is not worth mentioning farther.

A case a good deal different from this, occurred at Languard Fort, which is also situated by the side of the sea. In digging there for a well through a bed of sand, they found abundance of water; but, as this was below *high-water* mark, they considered it to be salt water, and it was owing to an accident alone, that they found it to be perfectly sweet. They continued to dig down, always finding abundance of sweet water, until, at the depth of twelve feet, they found it suddenly to become more abundant, and perfectly salt. On examination, it was discovered that the salt-water was found exactly at the height of *low-water*; and that all above low-water mark, afforded sweet water only. This phenomenon was evidently owing to the salt-water having had time to penetrate backwards to a great distance, where the sand was below the level at which the
sea

sea stood continually; but, between high and low water mark, the fresh water in its passage towards the sea, though stopped for a time by the salt tide, yet still pressed forward, and retarded its passage back through the sand: Nor is it to be doubted, that, if free access had been given to the water into the well, while the sand was kept back, that the water in this well would have risen higher at flood, than at the ebb tide.

But, not to dwell on this unimportant circumstance, the practical inferences that may be drawn from these two cases, are important. In the case of Sheerness, no enemy from without could ever entertain the most distant hope of intercepting the water from the fort. The thing is seemingly impossible. In the other case, the water could be cut off by a besieging army without much difficulty, if the country should happen to be pretty level; for they would have only to draw a trench between the high land behind and the fort, till it reached either the bottom of the pervious stratum, or attained the level of *low* water, and

and the business must be effectually completed.

Another practical inference may be drawn from the case at Sheerness which I may be permitted to mention. Should the flat ground continue for ever so great a distance backward, there can be little doubt that through the whole tract between the fort and the higher ground, water will be found, by boring, every where, that will rise in the wells always to the same level with the well in the fort: for the underpervious stratum must of necessity be continued from the higher ground, or it could not have possibly risen in the well at all.

• Another practical inference to be drawn from this case is, that as wells of fresh water are sometimes found to rise to the surface of the ground, or near it, in small islands, that are at a distance from the land, there can be no doubt, but in every case of this sort a pervious stratum, covered by one of impervious matter, must run the whole way from the higher land, under the sea to the island, as at Inch Keith, and Inch Colomb, both in the Frith of Forth; and that, of course, water will be found

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found in that direction every where, if dug for to a proper depth, which will rise to the same level with the well in the island. Hence, if water be wanted on the sea-shore it may undoubtedly there be found.

Again, There are a few instances of abundant springs of good water being found on the top of some small peaked hills, of considerable altitude, which are detached from all other hills by surrounding vallies. In every case of this sort, it must be occasioned by a natural perforation, of the same kind with an artificial tap-hole, which reaches lower down than some part of the valley around, which divides it from higher ground at some greater or smaller distance, having a bed of clay lying above the pervious stratum the whole way. This being the case, there can be little doubt, that every where between the higher ground and that hill, springs will be found by tapping, which will rise to a greater height at first, at least, than the surface of the ground—but it is by no means impossible, that if these tapplings be abundant, the well on the hill will be dried up. Indeed, this is not only not impossible but highly probable.—Hence, a
fort

fort in that situation, may be very easily reduced to a great distress by a philosophical general who besieges it.—This cannot be done in the low situation of Sheerneys; nor will the same reasoning apply in all cases to springs upon detached mountains, where the summit is more flat and of large extent, and the spring of water not very abundant.

Here, also, it may afford satisfaction to some persons to be informed, that the use which is proposed to be made of water sinking from above into internal cavities, for the purpose of turning machinery (p. 158) is not without example; for, there is a mill of this kind, at a place called *Moulins*, (I quote from memory) in the district of Neufchatel, in Switzerland, where the water, which falls into a gulf in the mountain, turns the wheel; the mill itself, and all the machinery belonging to it, being entirely under ground.

It may be here also remarked, that Dr. Derham, having found a spring at Upminster, in Essex, which continued at all times nearly at an equal height, both summer and winter, wished to infer from
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that fact, that all springs derived their origin from the sea. This phenomenon, however, has been explained in another manner, by the well near Leith (p. 121) which is a case that is by no means rare. It may, indeed, often happen, that a well of this kind may be found lying directly above another spring of the *tap*-kind, which may be made to rise to a great height above it, and which also shall continue always at the same height nearly. These corollaries are so obvious, as to require some apology for stating them—But when *common things* are represented as *mysterious arcana*, it is proper that the veil which covers them should be, in some measure, withdrawn.

After perusing the above, and adverting that there is not a single principle here illustrated, which was not clearly explained in these Essays, more than twenty years ago—(the single case of draining thin clays alone excepted; all that is added here being only illustrations of the principles already fully enough explained to every philosophical enquirer) the reader is left to judge with what propriety the BOARD OF AGRICULTURE
has

has prefixed the following exordium, to their account of MR. ELKINGTON'S Mode of Draining Land:

“ It is (say they) a circumstance hardly to
 “ be credited, that the principles on which
 “ the draining of land depends, should have
 “ remained *so long unascertained*, consider-
 “ ing the great private benefit, and the
 “ many public advantages, which must ne-
 “ cessarily be derived from carrying so im-
 “ portant an art to perfection !!!”

Mr. Arthur Young, in one of his performances, tells us, that he attended a *seance* of a society of philosophers, in France, who had met for the purpose of improving agriculture, the importance of whose deliberations, and the wisdom of whose remarks, he does not mention in terms of the highest respect.—I am well pleased to excuse myself for not quoting the passage, from my being at present deprived of books.—It would be well if that gentleman would take care to have things so well arranged at home, as not to give occasion for strangers, to retort upon our own dear nation, in a similar manner.

Fig. 29

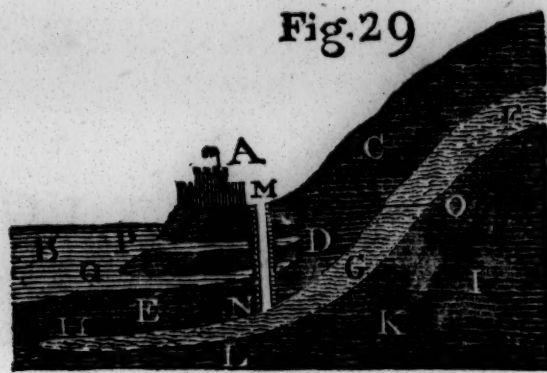


Fig. 30

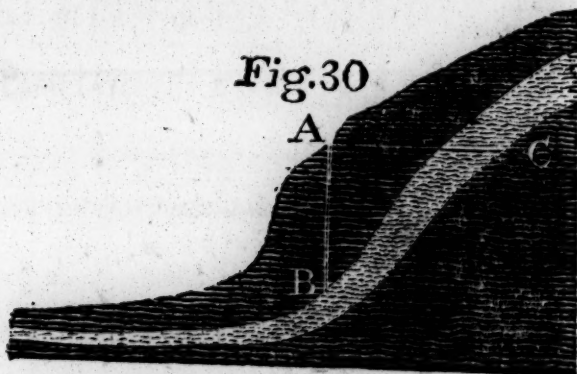
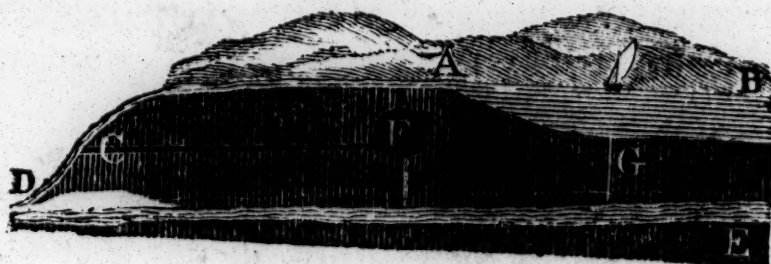
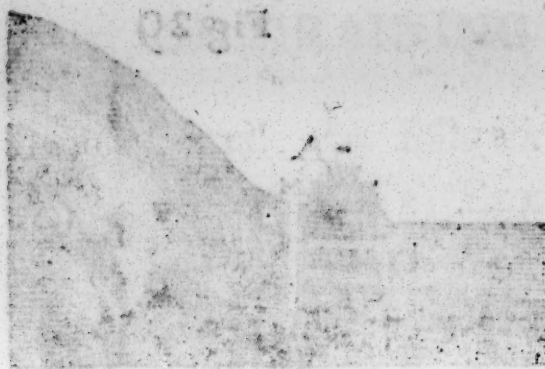


Fig. 31



Fig. 32





ADDITIONS

MADE TO THE FOURTH EDITION

OF ESSAYS, RELATING TO AGRICULTURE
AND RURAL AFFAIRS.

Of the Uses of the Balsam Poplar in Fencing.

WHEN the First Edition of these Essays was printed, the Balsam Poplar was scarcely known in Britain. It is now sufficiently known, as a healthy free-growing tree ; and, while young, it is particularly attractive, on account of the firmness and luxuriance of its shoots, the grandeur of its large leaves, especially in autumn, and the fragrancy of its buds, in the spring. These circumstances induced me to propagate it in considerable quantities, a good many years ago, —and as it can be multiplied with as much facility as the common willow, by means of cuttings, I was gradually led to perceive

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that it possessed certain peculiarities, which rendered it more valuable as a fence, than any of those already enumerated. It has more firmness and stability than the willow—is more luxuriant in its growth than the Lombardy poplar,—and advances more steadily in its progress towards a tree, than the elder; so that, under judicious management, I have found it the cheapest, firm, quick-reared fence for rich lands, in this country, that has ever yet come to my knowledge; on which account, I think it my duty here to describe the mode of management, under which I have found it prove a most useful assistant to the farmer:

For obvious reasons, the person who wishes to avail himself of this kind of poplar, as a fence, should begin with rearing his own plants—and for that purpose the *richest*, mellowest, and tenderest soil he can command should be made choice of as a nursery.—If it has a small tendency to dampness, so much the better—but if it go so far on that side as to be denominated wet land, it will not answer quite so well.

well.—Cuttings from well ripened wood, of two years growth, are best ; but where they are scarce, others, older or younger, need not be rejected. The cuttings may be about one foot in length, and should be planted in rows, about eighteen inches distant, and three inches between each plant in the row. Autumnal planting succeeds best ; but they will do also in the spring. Their tops should not be left more than one inch above the ground. When they begin to push out their buds in the spring, a careful person should be made to go along each row, rubbing off with his thumb every bud he sees, except one, which in this case will soon push up to be a vigorous stem, without collateral suckers to weaken it. This operation, if carefully performed, will not only make much better plants than otherwise could have been obtained, but it will save a great deal of expence that must have been incurred, had it been neglected.

Nothing more is wanted but to keep the ground clean between the plants, and to dig it over between the rows, at least

180 A NEW KIND OF FENCE

once a year ; for the ground for this plant cannot be kept too rich and tender. If justice has been done to it in all respects, the plants, in general, will reach to about four feet in height the first season ; and in two years more, or at the most three, they will be large enough for planting out where the fence is meant to be.

/ Rich arable or meadow land is that for which this fence is the best adapted ; and as this plant requires to be planted on the flat surface without any ditch, and can never have the ground on which it is to grow too rich, it will be adviseable, in general, to plough up a narrow ridge where the hedges are meant to be planted, so early as to admit of its being four times, at the least, ploughed, before the time for sowing of turnips. Let it be very richly dunged, and put into turnips, in drills about sixteen inches apart, and properly hoed ; after these are drawn, the ground may be either ploughed or dug, and harrowed smooth, to prepare it for being planted.

The ground being thus prepared, let
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the plants (which will now be from 10 to 12 feet high, and from one inch, to an inch and an half diameter at the root) be taken up from the nursery, and carefully sorted, so as to be all nearly of the same size, which are to be planted together. Let a mark be then made in the middle of the ridge, where the centre of the hedge is to be, and stretch a garden line, parallel to that, nine inches from the centre; then let one man with a spade begin to open a hole on the outer side of the line, sufficient to receive the roots of one plant, and let an assistant put the plant into that hole, flanting the top of the plants to an angle of about 45 degrees to the horizon. But, instead of laying these parallel to the line, let them slant so much inwards, as that every plant, at the height of four feet above the surface of the ground, shall be right above the centre of the ridge, and proceeding in that manner, leaving an interval of about one foot, or fifteen inches, between each plant, go round the whole of the inclosure. When this is finished, move the line to the same distance (nine inches) from the middle of the ridge,

on the opposite side; begin, and proceed exactly after the same manner, to plant another row of poplars, in a direction the reverse from that of the former, so that if the tops of the one row lie to the eastward, inclining to the left hand when you look eastward, the tops of the other shall lie westward, inclining to the right hand, if you still look eastward; so that the two rows meet each other, at the height of four feet from the ground, exactly above the middle of the ridge. The whole row being thus planted, let the tops of both rows be plaited through each other, so as to assume a horizontal position, like the top of a rail; and the fence, when viewed sideways, will have somewhat of a lozenge-like appearance, but not crossed like the willow fence; but with this difference, that the stems are much thicker and stronger in every respect, and that they are not contiguous to each other, and cannot be wattled through each other, unless at the top only. This, then, forms at the very first moment after it is finished, a sort of living railing, of no inconsiderable strength, which, even in this state, will be a tolerable fence, and which

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in the course of a few months, will rise to five or six feet in height, so as to be an effectual screen against the severity of the weather, and which in the space of a few years, under judicious management, will have acquired so much strength as to be nearly impenetrable by animals of any sort.

In this way may be reared a hedge that will be a perfect defence against all the larger-sized animals, man only excepted; but, if it be intended to guard against the intrusion of boys, or smaller animals, the following precautions must be adopted:

When the hedge has been completed in the manner above described, let the earth at the roots of the plants be smoothed, and plant a young sweet-brier plant in the opening left between each two of the poplars, so that there shall be the same number of plants of eglantine, as of poplars; but let these eglantine plants be put about three inches farther back than the line of poplars, so that they may be about twelve inches distant the one row from the other. These plants should be of one

year old, or two at the most, for as it grows very quickly, it will soon reach the top of the hedge.

The first summer after planting, nothing more is necessary than to keep the bottom of the hedge free from weeds; and in the autumn, go over both sides, cutting away with hedge-sheers, all the shoots that come beyond the line of the ribs of the hedge, as the original stems may be called; then raking that rubbish back from the hedge, cut over with the point of the sheers, every plant of eglantine close by the ground, leaving the dead stems that are between the ribs of the hedge, without disturbing them. Next season, the eglantine will send out strong shoots from the bottom, which pushing through the dead branches of the former year's growth, will intermingle with them, and fix them firmly in their place, some of these stems also pushing through among the ribs outwards. In the autumn, once more, cut the sides with the sheers as before; and then, once more, also cut over the eglantine at the bottom, as in the former year. The matting of prickly-brier,
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in the heart of the hedge, will now have become very close, so as nearly to fill up the whole of the internal cavity originally left between the ribs; and the next year's shoots intermingling with these, will render it still closer. The sides of the hedge should be clipped every year, and the eglantines cut over as above described, until the whole of the bottom part of the inside of the hedge shall become as close as you wish it to be, so as not to suffer a fowl, or any animal of that size, to be able to creep through it; after which time it will be only necessary to cut the *sides* of the hedge annually, so as to give it an external coating of living eglantine, which will form a fence the most impenetrable, as well as the most beautiful, that can be conceived. To add to the beauty, a few plants of honeysuckle may be planted along the hedge, and some of the freest shooting roses, particularly the white rose, interspersed through it, which will thrive abundantly.

The shoots on the top of the hedge may be allowed to run upwards, till they have acquired the size you wish for, or
have

have attained to as great a height as you would incline; when they may be cut over, at four feet from the ground, and applied to the purposes you find most useful, or for fire-wood, of which they will afford a very great quantity. After being thus cut over, they will send forth shoots, in general, which will reach to nearly five feet high in one season, and about the thickness of a man's thumb at the under part. In three years, they will be as thick as the wrist, and very tall.

This kind of fence, I have actually reared, and I can safely recommend it as the cheapest, the most quickly reared, the strongest, the most beautiful, the most durable, and in all respects the best kind of fence for rich land, I have ever seen; and I consider myself as fortunate, in having stumbled upon a thing, which for more than forty years I had considered as a desideratum in agriculture, that I never hoped to see supplied, viz. a fence which for the expence of two-pence the yard, at the very highest estimate, can be made so as to be nearly sufficient as soon as it is done up; which can be kept in complete repair ever afterwards,

afterwards, without any expence (for the loppings, in every situation, will be worth more than the expence of pruning them); and which will far outlast the greatest period of human life; being a complete defence, at the same time, against the strongest, as well as almost the smallest noxious animals of every sort.

The intelligent reader will easily perceive why the ribs were made wider at the bottom than above; for in this way alone, could the sides of the hedge be kept alive and close the whole way of the bottom.

I need not add, that, however adviseable this kind of fence may be in rich lands, it could not be made to thrive on a poor soil, so that it should never be attempted on such land.

For the uses of the larch-tree in fencing *barren* ground, the reader is referred to the Third Volume of these Essays.

188 ON MILL-DAMS, OR WIERS,

*Of the best Method of Making Mill-dams,
or Wiers, Heads, or Breasts across Rivers.*

I KNOW of no species of fence upon which more money is generally expended, than that which forms the subject of the present article: for, though I hope to be able to show that it may be easily effected, yet, as it has been hitherto executed, it is not only expensive on its first erection, but is so liable ever afterwards to sustain damage from floods, that it is a source of never-failing disquietude, and endless charge, to the owners of such works.

Hitherto, it has been customary to make the dike which forms the mill-dam, head, or wier, which runs across a river, universally of a triangular form, being wide at the base, and growing gradually narrower towards the top, where it ends in a kind of point, as in the margin, than which no form can be devised, that could be weaker, or more liable to accidents. The
force



force of running-water, when its velocity is accelerated by falling from a considerable height, upon bodies that oppose its motion, becomes nearly irresistible; and, in this mode of constructing a dam, the artist seems industriously to have aimed at giving an example of the power of water, under these circumstances: for no sooner does that water shoot over the uppermost stones of the dam, than it precipitates itself with violence upon those stones on the lower side of the inclined plane, which are made to project beyond the first—but which are thus made to sustain the whole force of that concussion. From one stone it proceeds to another, and another, still acquiring additional velocity, till it reach the bottom of the inclined plane; and, if the height be considerable, it is easy to see that the force of the water, before it reaches the bottom, must have become such, as to be capable of displacing the largest stones that the power of man can place in that position*.

* The water too, which rushes through between the crannies of the stones every where, especially where the mound is of considerable height, is so powerful, as to displace the materials in every part, and greatly accelerate the ruin.

Thus

Thus it has happened, and ever must continue to be the case, that every weir which is constructed on this principle of rough unhewn stone, is, from time to time, liable to be swept entirely away, so as to lay the machinery waste until it be again rebuilt ; which frequently happens at that season of the year, when such operations are the most troublesome and expensive.

The frequent recurrence of such accidents has induced some owners of machinery to erect their weirs in a very expensive manner at first, by building the whole triangle of hewn stone, the surface of which is so smooth, as to suffer the water to glide over it, without being able to insinuate itself so readily between the crannies as in the former case. Much good likewise, some are inclined to think, may be derived from giving the surface of the weir a particular form of curvature, which I do not think necessary here to dwell upon. This is, indeed, found to give it some additional security ; but, unless the whole be battled together with bats of iron, it is still found to be insecure ; and the expence, where

where such battering is attempted, is such as to prevent it from being carried into effect, unless under very particular circumstances.

Fortunately, however, for those who have works of this kind to accomplish, by adopting a more judicious mode of construction, they may rear a dam that will be equally strong with the inclined plane, when made of *hewn stone, or even when battered with iron*, at an expence not greater, at least, than would have reared one, of the rudest construction, of common stones.

The reader, from what has been already said, will easily perceive, that the chief circumstances which are wanted to give stability to the dam, are, to remove the stones out of the way of the falling water, so as to free them from running a risk of being displaced by it in its fall, and to prevent the water from being forced violently through the crevices of the mound towards the bottom; he will also perceive, that the first part will be easily effected; merely by making that side of the breast which looks towards the lower part of the river, a perpendicular wall, instead of an inclined plane—for in this case the water, when it is
forced

forced over the top of the dam, with the velocity it necessarily acquires when in a flood, will shoot over clear, without touching any part of the perpendicular wall, exactly in the same manner as it shoots over a perpendicular rock, in a natural cascade. This is so obvious, as to need only to be stated, in order to be recognized as unexceptionably just, by every person who shall bestow a single thought upon the subject. It is indeed so obvious, that it must excite some degree of wonder, it should not have been long ago carried into universal practice.

It is not, however, a matter of great difficulty to account for the manner in which mankind have been led into a general persuasion, not only of the *utility* of the triangular form of a double inclined plane, but even of the *necessity* of it, for giving strength to the dam dike. It is very obvious, that if a strong force were applied to one side of a perpendicular wall, tending to push it over, that wall would receive a great additional support, were a strong beam of wood placed in a diagonal direction upon the side of the wall, opposite to that to which the pressure

pressure was applied—it is exactly upon this principle that the buttress of stones, thus applied, has been supposed to strengthen the dam dike—for as the water, flowing forward, apparently tends to force the wall forward along with it, the buttress seemed to be necessary, to enable it to bear that pressure, without being carried away along with it.

But here it deserves to be remarked, that there is a great fallacy in this mode of reasoning, as applied to this case. The strength of a wall for resisting the force of water, depends chiefly upon the absolute weight of the materials of which it consists; and if these materials are of such a form as to make the water press perpendicularly on any part of it, the very weight of that water, if the materials resist the entrance of water, will add something to its solidity. Now, as there is nothing to prevent you from adding as much thickness to the wall, as the circumstances of the case shall render necessary, the buttress on the *under* side may be removed, without the smallest danger of rendering it weaker in any respect;—and, for the reasons already given, it ought most certainly to be removed.

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forced over the top of the dam, with the velocity it necessarily acquires when in a flood, will shoot over clear, without touching any part of the perpendicular wall, exactly in the same manner as it shoots over a perpendicular rock, in a natural cascade. This is so obvious, as to need only to be stated, in order to be recognized as unexceptionably just, by every person who shall bestow a single thought upon the subject. It is indeed so obvious, that it must excite some degree of wonder, it should not have been long ago carried into universal practice.

It is not, however, a matter of great difficulty to account for the manner in which mankind have been led into a general persuasion, not only of the *utility* of the triangular form of a double inclined plane, but even of the *necessity* of it, for giving strength to the dam dike. It is very obvious, that if a strong force were applied to one side of a perpendicular wall, tending to push it over, that wall would receive a great additional support, were a strong beam of wood placed in a diagonal direction upon the side of the wall, opposite to that to which the pressure

pressure was applied—it is exactly upon this principle that the buttress of stones, thus applied, has been supposed to strengthen the dam dike—for as the water, flowing forward, apparently tends to force the wall forward along with it, the buttress seemed to be necessary, to enable it to bear that pressure, without being carried away along with it.

But here it deserves to be remarked, that there is a great fallacy in this mode of reasoning, as applied to this case. The strength of a wall for resisting the force of water, depends chiefly upon the absolute weight of the materials of which it consists; and if these materials are of such a form as to make the water press perpendicularly on any part of it, the very weight of that water, if the materials resist the entrance of water, will add something to its solidity. Now, as there is nothing to prevent you from adding as much thickness to the wall, as the circumstances of the case shall render necessary, the buttress on the *under* side may be removed, without the smallest danger of rendering it weaker in any respect;—and, for the reasons already given, it ought most certainly to be removed.

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There is not, however, the same reason for removing the slope on the upper side of the wall; on the contrary, the farther it is filled up above the breast, and the more gradually it shelves downward there, the firmer it will be: for, as the water presses with a force exactly proportioned to its perpendicular depth, if the mound be broad enough, at the bottom, where the pressure is, of necessity, greatest, there is no necessity of having it broad at the top, where that pressure is diminished almost to nothing. The easiness of the slope, too, is well adapted for preventing the current from striking with great force upon it; or other objects which may be forced down with the stream, from laying violent hold of it, and tearing it forcibly asunder. Nor is it a matter of great difficulty to make such a mound; for, as the water above the dam is nearly stagnant, any kind of loose stones, or gravel, or other rubbish that is not soluble in water, will be in no danger of being displaced by the stream, but will lie there undisturbed, if they be thrown in any-how, at random.

These principles being thus explained,
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I shall subjoin a few brief directions for constructing bulwarks of this sort, which, if carefully adverted to, will seldom fail to give satisfaction to those who shall adopt them.

It needs scarcely be observed, that in building this kind of wall, as in every other wall whatever, it is necessary to dig, till a firm foundation be found.—Rock is the best, where it can be reached, for obvious reasons. Where the bottom is only gravel, a wide trench should be made, for a considerable depth, which ought to be, at least, six or eight feet in width. All the rubbish that comes from this trench should be thrown to the *upper* side of the dam. The wall should then be built, two, three, or four feet in thickness, as circumstances shall indicate; the higher the dam, the thicker, always, should the wall be. But few cases occur, in which more than two or three feet are absolutely necessary. The stones in this wall should be bedded with as great care as possible, without any mortar, or with tarras at the bottom, especially if any mortar be used, and as few little pin-nings be put in among them as may be.

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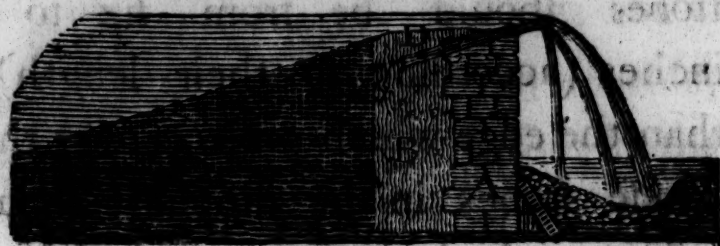
And, as it is of great consequence for preventing the waste of water, but still more, for rendering the wall firm and durable, that no water should leak through the dam, the opening that is left on the *upper* side of the wall (which, in no case, should be less than three feet, and, where the mound is high, five or six feet will be better) should be rammed full of clay, regularly as the wall rises upwards. When the wall reaches near to the height that is required, it ought to be brought to a true level across the river, its whole length, and upon the top should be laid a coping of flat stones of as large a breadth as they can be got, and neatly cut, and closely joined in every part (where this cannot be had, or where it is required to project very far, planks of oak-wood may be adopted in its stead). This coping of flat stones should project over the perpendicular wall, on the under side, as far as the nature of the materials will allow; and on the other side, it ought to extend as far as the length of the stones will permit, being so laid as to slope downwards, towards the upper part of the river, in such a man-

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ner as that the dipping edge of these stones should be from six to twelve inches (according to their length) lower than the edge which projects over the wall. These stones in the dipping lip ought to rest upon the bed of rammed clay, which should rise higher than their lower lip, and overlap it in part, and if the flat stones cannot be made to join so close as to be water-tight—some clay ought to be laid below them, so as to prevent the water from sinking down through the wall, which is always attended with danger. Small stones may safely be rammed into that clay, and it ought to be covered with gravel, which should rise nearly, but not quite so high as the projecting lip of the coping of the wall. Stones, rubbish, or gravel should be then tumbled down carelessly into the bed of the river *above* the dam, so as to fill it up, as far as can be done at a moderate expence, making it to shelve gradually downwards from the dike into the water; and it will be adviseable, where conveniency permits, to have the whole of this bed to be puddled, so as to make it carry the water through it without
O 3 sinking.

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sinking. The figure annexed represents a section of the whole when finish-



ed, in which A is the wall ; B the bed of clay, intermixed with stones rammed firm ; C the coping ; D the loose stones and gravel covering the whole, and extending forward in the form of an inclined plane beneath the surface of the water in the dam.

By inspecting this figure, the use of the projecting lip of the coping will be apparent. It serves to throw the water clear over, so as to make it fall at some distance from the bottom of the wall. This distance will be greater when the river is in flood than at other times ; of course, it will have a tendency to make a cavity in the bed of gravel at some feet distance from the wall, so as to be in no danger of undermining it. But should any danger of this sort be apprehended, a row of flat stones (or, for want of these, a plank of oak) placed along the bottom of the wall, leaning towards it at top—and sloping some inches from it below,

below, the under part of these stones being sunk as deep at least as the foundation of the wall, and then covered up with gravel, will effectually secure it. Though this is rather a superfluous precaution.

I beg leave here to repeat, that great care be taken to make the wall, through its whole length, as true a level as possible, that the sheet of water may be spread over the whole of an equal thickness, during the floods, which will tend to moderate its force very much. I need scarcely add, that in laying out the direction of the wall, it should never be suffered to come so near a rock in front of it as to endanger a powerful eddy being thrown back upon the wall to endanger it—this being obvious to every considerate person. Where the head is thus made perfectly level and smooth, it will often happen that the stream of water which flows over it for the greatest part of the year, will be so thin as not to prevent the growth of aquatic grasses near the top, which ought not to be discouraged—for which reason a little mould among the surface gravel (which ought always to be small) will do no harm.

I am aware of one objection to the mode of making dams here proposed (which, indeed, affects all the other contrivances in this Volume) viz. that it is so simple, and so little expensive, as not to be calculated to catch the attention of men, like those vast projects which have the *grand* and *wonderful* to recommend them. It proposes only to benefit those who are attentive to their own interest and a judicious economy. A time may come, however distant, in which these may be deemed objects of great national importance.

It will also be objected, that the stones will be in danger of being *sucked* out of the wall, so as to undermine it, and make it tumble down; this being an accident to which breasts on the modes of construction now in use are extremely liable. It becomes, therefore, necessary that the reader should be here directed to attend to the circumstances which have been here adopted with a view to obviate this evil, that the structure may be so carefully erected as to be in no danger of being deficient in these respects, so as to render the work of no value.

In the first place, you will please to ad-
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vert to the bed of clay, rammed in upon the upper side of the breast ; care should be taken that the foundation of this clay bed be dug so deep as to reach the solid bottom—and that the clay *there* be very carefully rammed down, so as to leave no passage for the water at that place, or anywhere else ; for if water should force its way through any small crannies towards the bottom, especially where the breast is of great height, it will force its way with so much impetuosity as soon to widen the breach, and carry every thing before it.—It is chiefly because of the neglecting this precaution, that breasts for water are in general so unstable. With a view to give mounds of this kind stability, it is usual to throw in a great quantity of *large* stones in the place that is here occupied by the clay, than which nothing could be more injudicious—for the water always finds an easy passage among these stones—and infallibly must *suck* out, as it is technically called, the lower part of the mound.—This is the unobserved cause of the sucking out of walls, as it is called, which has been commonly ascribed to the eddy from below.—We shall soon have

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have occasion to take notice of other benefits that are to be derived from this bed of clay.

In the second place, the levelness of the top of the breast is of great consequence for giving stability to the work; for by this means the sheet of water, by being extended equally to a great length, is extremely thin in every part, and, consequently, its force is much less considerable than when it is deeper in one place than in another; where powerful streams are formed, which dig out pits below, that are extremely troublesome and dangerous. This circumstance ought therefore to be attended to with great care.—For the same reason, the longer the breast is, the safer it will be, where this circumstance is adverted to.

Thirdly, the coping at top ought to project as far over the wall as possible, and to be cut quite even in the edge.—By this means, the water is made to shoot clear over the breast so as never to touch it, and is of an equal thickness in every part. This is a contrivance that has never yet, that I have seen, been introduced into practice, and from the want of it, much mischief is produced.—

For,

For, where this is wanting, the water in its fall striking on one stone after another, with the accelerated velocity it acquires in its descent, soon insinuates itself among the seams—sucks out the smaller stones, and thus throws down the whole fabric.—The cause being thus removed, the effect, of course, will not be felt.

Fourthly, in consequence of the shoot that the water acquires, the place where it falls at the bottom will vary with the force of the current.—When the stream is low, the water will fall almost perpendicularly down: when higher, it will shoot over to a greater distance; and when it is in a flood it will force itself over to a still greater distance.—But when the water falls down perpendicularly, it has so little force as not to be able to derange any thing—when higher, it acquires more force, and pushes more forward—and when in a high flood, it pushes forward with the greatest impetuosity, and falls at a distance from the breast proportioned to the quantity of the water, and the height of the fall.—It is, of course, at the place it now reaches, that it digs the deepest pit.—Hence, then, it would follow, that
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should the water, when it shoots over the head, alight upon a bed of gravel, it would work for itself a pit, not close by the wall, but at some distance from it; and that distance would be the greater, the higher the head from whence the water falls, so as to form the bottom of the pool, shelving upward, to the wall, as in the figure;—thus the foundation of the wall would be in no danger of being undermined.

But should any danger of that kind be apprehended, where the fall is great, and the bottom soft (a bed of clay, for example) it may be adviseable rather to prepare a proper basin for the water, than to leave it for nature to form one for herself. With that view, let the bottom be scooped out, as in the figure, so as to make a deep pool, into which the cascade may fall. The depth of this basin may be augmented, by raising a kind of bank of gravel or loose stones before it. In this way all danger of undermining the foundation will be avoided; the force of the fall being broken by the water, before it reaches the bottom. If the bottom be very soft, a little gravel may be thrown into it, to defend it; no
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kind of shoeing, where the pool is deep enough, can be required.

There is only one case I know of, where the wall runs a risk of being hurt by the water, after it has made its shoot, viz. when the falling stream strikes upon a shelving rock which inclines towards the wall, so as to drive an eddy back upon it, or make it wheel round in an irregular kind of current. The easiest cure in this case, will be to dig out the rock where it is so circumstanced, and to form a deep pool in its place—the materials taken away can always be usefully employed in making the *head*. But if, after all, any danger should be apprehended, from any kind of eddy below sucking out the stones, that may be very easily and effectually prevented, by laying a few planks of oak along the whole length of the lower part of the wall, on whose smooth surface the water can take no hold, and behind which the stones will be effectually secured. I need hardly observe, that where any thing of this sort is intended, care should be taken to put some knots of oak into the wall, at proper places, when it is built, for the purpose of securing these planks.

Neither

Neither is it necessary for me to enlarge upon the necessity of augmenting the thickness of the breast wall, where that is required to be made of an unusual height---that being a thing so self-evident, as to be understood by every ordinary mechanic. It may not, however, be improper to remark, that a wall which is strong enough to support the same quantity of loose materials as the mound consists of, that lies on one side of it, is all that is required. This is necessary---but no person of sound judgment will choose to go to the very limits of possibility in a case of this sort---it is always safest to err on the side of excess, so that the wall should be made so strong as to remove all doubt.

*On the Means of preventing the Sea from
making Encroachments on the Land.*

WHEREVER water is in motion, it is perpetually producing changes on the surface of this globe, which at times prove highly beneficial to individuals; but more frequently hurtful, seeing the ravages produced

duced by that element, which, when directly opposed, is found to be often irresistible, are frightfully destructive. In the preceding pages, some directions, which have never been found to fail in any one instance where they have been followed, have been given, for securing the banks of *rivers* from the devastations by running waters. I now propose to add a few hints concerning the most efficacious means of setting bounds to the raging fury of the *ocean*.

The principle upon which the force of water can be effectually resisted, is precisely the same in all cases: so that, in strict propriety, little can be added to what has been already said, farther than to show in what manner the same principle can be so managed, as to apply, with the best effect, to the different cases, as they shall occur.

That water, when strongly agitated, can best be resisted by gently yielding to its influence, and not directly by opposing its impulse, is a truth that cannot be denied, and never ought to be lost sight of in every operation, in which that powerful agent is concerned. In conformity with this principle, it is found, that where the sea-beach

is low, the land is rather, in general, encroaching on the sea than the reverse--- but wherever the shore is steep, the sea is making encroachments upon the land, which are more or less considerable, according to circumstances. Where rocks oppose an impenetrable barrier, they are little altered for ages ; for, although immense masses of rock are sometimes overturned by the raging fury of the ocean, the progress it makes in such cases is so slow, as scarcely to be perceptible ; but wherever the sea approaches a perpendicular cliff of clay, or penetrable mould, it encroaches with hasty strides ; and sometimes carries off whole fields of good land, by the devouring sweep of one furious tide.

To guard against this evil, several contrivances have been adopted, most of which have been so expensive and inefficacious, as to compel those who are sufferers by this misfortune, to be often obliged to remain inactive spectators of the ravages to which they are incessantly exposed. The general mode that has hitherto been attempted to stop the progress of this evil is, to erect a strong bulwark of large stones *in front of the bank,*

bank, piling these stones above one another as carefully as possible, so as that the front exposed to the sea, slopes gradually backward towards the bank above, to which it finally joins, at such a height above the sea as the undertakers are able or willing to make it.

Every bulwark of this kind is liable to be destroyed by one or other of the following circumstances, all of which, on some occasions, co-operate, so as to get it thrown down, nearly in as short a time as was required to rear it up : 1st, If an individual has only a share in the property of such a bank, and those on either side of him neglect to fortify their property, the sea, making encroachments at either end, leaves his bulwark *there* exposed to the fury of the elements, so as to stand in need of perpetual repairs ; or, 2d, Although this evil should be avoided, the sea, when furiously impelled by a storm, is forced up the inclined plane with great fury, and, when the wave falls back, the body of water that had been forced up, rushes back again over the stones of the inclined plane, with still greater force, like a cascade, so as forcibly to tear the stones out of their places, exactly

in the same manner that the stones of a mill-dam, of the usual construction, are displaced ; or, *lastly*, the water, in its return, insinuates itself between the stones and the bank at the top, where the stones join to the earth, and there scoops out the earth, so as to leave the stones defenceless from behind, and thus exposed to be tumbled headlong down, by the force of the cascade, occasioned by the revulsion of the tide. Nor is it possible that this evil should ever be obviated, unless the inclined plane of stones should be carried to a greater height than the water can ever be forced to rise, by the accumulated force of a high tide, impelled by a storm ; a thing that, if it could be accomplished by human power, would frustrate its own aim---for the cascade would thus become so much lengthened, as to give the revulsing tide an irresistible power over the stones toward the bottom, that must tear them from their places in a short time, and scatter them about like pebbles on the sea shore. Thus would reason decide on the probable consequences of attempting to secure property, by means of such bulwarks ; and experience has fatally confirmed the justness

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of it, by the example of numberless individuals who have had the misfortune to attempt it.

Wherever a cure is practicable, it must be effected by a procedure, in almost every respect, the reverse of the above. Large stones, instead of being gathered together there, must be carefully removed from the beach ; for wherever a large stone is suffered to remain near the sea-shore, between wet and dry, as it may be called, it infallibly produces a whirling eddy, which prevents the sand and gravel from ever attaining that smoothness of surface which alone can mitigate the fury of the waves, and prevent them from scooping out the earth near the sea-shore. Thus it happens, that wherever many large stones are permitted to remain near the shore, the sand and small gravel, instead of being suffered there to remain till it be accumulated into a solid bed, that gradually rises above the level of the sea, is whirled about by an uninterrupted agitation, among the stones, till it, at last, makes its escape from among them, and is suffered to remain at rest, on some less perturbed part of the shore, and

there to form a bulwark to protect that place from farther encroachments; whereas, that part of the shore where the great stones are suffered to remain, must continue nearly at the same depth, for ages, and suffer the defenceless coast, behind it, to be infallibly exposed to the encroachments of the sea, until that nuisance shall first be removed. By adverting to this circumstance, and carefully attending to the natural operations of the sea, in cases of this sort, we shall be enabled gradually to perceive by what steps the evil complained of may best be guarded against.

When the sea washes down a great body of clay, or other kind of earth that is easily diffusible in water, the whole of that diffusible earth is quickly mixed with the agitated water, and with it is carried far away, until it reaches some place where the water is suffered to remain so long at rest as slowly to allow it to subside. There it forms beds of that soft kind of mud, called fletch, which, when they gradually rise above the surface of ordinary tides, become, in time, covered with herbage, and, at last, form those rich grass lands,

lands, known by the name of *salt-marshes*. While this operation is going forward, the sand, gravel, and stones, which were intermixed among the earth, in its original state, being more weighty than the other component parts of the mould, are deposited near the bottom of the bank from whence they originally came ; and if these materials be abundant, and few large stones among them, the bed of sand or gravel thus accumulated, rises, in time, above the surface of the sea, and forms that kind of natural sea-beach, which is found along the shore, in most places, where no sensible encroachments of the sea are perceptible. But if little sand or gravel be contained in the bed of earth that is washed by the sea, especially if that bed of diffusible earth reaches deeper than the surface of the water, the quantity of gravel or sand is too small to fill up the void that is occasioned by the washing of the sea, and the water continues deep *to the very edge of the bank*. Where this happens to take place, it is a very hopeless case ; and it will be found a matter of great difficulty to effectuate a radical cure—but, fortunately, this is a case

that very seldom occurs ; so seldom, indeed, that I have never seen one of the kind. In general, there is such a quantity of sand or gravel accumulated at the bottom of the bank, as to raise the beach there above the surface of low-water mark, —frequently above the surface of high-water mark, neap-tides ; so that it is only at *spring tides*, or during storms, that damage is sustained. Where this is the case, the evil may be obviated, in most cases, at a very small expence ; and, in no case, will the expence be extravagantly high, if the following mode of procedure be adopted :

Let a trench be first opened in the sand or gravel, ten, twelve, or twenty feet wide, running in a direction perpendicular to the shore, right into the sea. This ditch should not go deeper than the sand or gravel, nor need it be made more than one foot in depth, unless as afterwards excepted, let the gravel be of what depth it may. This trench may be carried out farther or shorter as circumstances shall indicate. As soon as the trench is made, fill it up with earth dug from the bank immediately behind it, taking care to pick out the large stones that
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happen to be among it. Lay this earth so as to slope gradually upward towards the land, rising in a regular slope, with an angle between 10 and 20 degrees from the horizon, continuing the slope in this manner till the top rises higher than the highest rise of tide when agitated by a storm. When this trench has been thus filled up with the earth, taken from the bank—open a fresh trench, of the same breadth, at one side of it, in the gravel, covering the surface of the earth that has just been laid down, with the gravel that is taken out of the trench, so as to cover that new-laid earth with a bed of gravel about one foot deep over the whole. Let the second trench be filled up and covered in the same manner, and so on, till the whole be finished.

If the bank of earth be not very high, and the shore over which the tide flows does not dip much, the inclined plane may be pushed so far forward into the sea, as to consume the whole of the earth that must be taken from the bank, to bring it to a regular slope to its full height. The advantages to be reaped from this mode of procedure, will be, 1st, That the earth will thus

be removed at the least expence possible—
2d, That the gravel will require to be moved to a smaller distance, for covering it, than would otherwise be required; and, lastly, that no ground will be lost, but rather something will be gained from the sea.

But where the shore dips very fast from the beach, it may perhaps be impossible to proceed after this manner, so that the slope must be made chiefly backwards upon the land; and in that case it will be necessary to dig the trench as deep in the gravel near the shore as can be conveniently done, in order that a quantity of gravel may be thus obtained to cover the earth as far back within land as possible.

Please, however, to observe, that the new-made earth will gradually subside, and that the part of the slope which is continued back *upon the solid ground*, will not subside at all; so that if no precautions were adopted, there would soon happen to be a breach at this place, which would render the bank vulnerable.---To guard against this evil, therefore, be careful to ram the new-laid earth as firmly down as possible, especially near the joining; and
also

also to trench over the surface of the solid bank to a considerable depth under the slope, which will allow the earth there to subside a little, so as to keep them from separating.

The gravel ought to be carried up the slope as far at least as high water mark during the highest tides. Above that, the slope should be covered with a surface of vegetable mould, of as rich a quality as can conveniently be obtained, laid smooth, and sown with grass seeds---so as to bring it to a sward as quickly as possible. Over that should be laid, for some distance, a little gravel, which should become gradually thinner, as it rises higher, till it decreases to nothing. When this bank has become covered with a close pile of grass, such waves as may be accidentally pushed to an unusual height during a casual storm, will flow back over its smooth surface without breaking it. For obvious reasons, no stones or other impediments ought to be suffered to remain upon the surface of this part of the bank.

It will be unnecessary for me to give more detailed directions, concerning the variations that ought to be adopted as circumstances

stances differ, seeing that common sense, where the principle is well understood, will suggest all that is necessary to every attentive mind which contemplates the subject; and even if a volume were written upon it, there is little probability that all the variations of circumstances, which in some cases may possibly occur, would be adverted to. I shall therefore add no more than barely to suggest, that if the quantity of earth which requires to be taken away, be more than can be swallowed up in making the slope, perhaps the easiest way of disposing of it, after the slope is completed, will be to wheel or cart it down the slope at low water, as far as can be done, and there to throw it down loose, to be washed away by the returning tide---taking special care, in this case, to remove any stones that may be left---and not to allow a high mound there to accumulate.—If the bank be so very high, as to render it an object of great expence to carry the slope as far as the top of the bank, in that case the slope may be discontinued, when it has advanced so far as to be beyond the reach of the sea at the highest tides.---For, under these circumstances,

cumstances, though a part of the cliff may at times fall down merely from the effects of the weather upon it, yet the sea will not there make any farther encroachments upon the land.

In Holland, where the sea dikes consist almost wholly of loose sand, which is nearly in as great danger of being deranged by wind as by water, and where the smallest accident happening to them would prove fatal to many thousand persons, and entirely destructive of their property, they are under the necessity of adopting precautions for securing their banks that our situation renders, in general, unnecessary. In the most vulnerable places, they find the best defence they can adopt against the alternate attacks of the two elements, is to cover the slope of the bank with thatch, which is pinned down along their whole surface with care, in a manner that experience has taught them to be tolerably secure; but, as this thatch is liable to be deranged by various accidents, magazines of it are laid in at convenient distances, and men are appointed to examine the banks daily, along their whole length, each being charged to
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take care, that any derangement in his own division be immediately put to rights. I mention this, here, as a thing that ought to be generally known in this island, though it can scarcely ever be required in the cases of which I now treat---it is chiefly where wiers are attempted with a view to gain land from the sea, as in Holland, that it can be wanted.

Curfory Hints on the most beneficial Method of recovering low Land, in certain Cases, from the Sea.

ON the subject of gaining land from the sea, so nearly connected with that I have just considered—but upon which I do not mean to enter at large, in this place, I shall beg leave to suggest a single hint for farther consideration.—It is this : land is sometimes gained from the sea, by gradually rising in its surface till it be above the level of high water mark—sometimes by rising no higher than low water—and sometimes by making an inclosure, and pumping the water out from

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a depth

a depth below the lowest tide level, as in some parts of Holland.

In this country, in general, the greatest efforts that are made, have been to recover land that has risen above low water level, but has not reached to the height of high water mark, as in those large works in Bedford, Cambridge, and Lincoln-shires, in which the ground is so low as to be much incommoded by water—and, according to the mode of procedure that has been adopted, it seems to be in no train of ever being better, but perhaps rather worse, if the same system should continue to be followed.

To obtain ideas on this subject, it is necessary to advert, that the extensive marshes here named have been produced by a gradual deposition of mud, continued for ages, which has been carried down by the large rivers which there disembogue into the sea: for the current of these rivers being there met by the sea, occasioned a stagnation of the muddy waters during the full tide, which, while in a state of rest, deposited its mud, and flowed off at ebb-tide much purer than before. The bottom thus gradually rose higher till it got above
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the level of low water, in which state a few aquatic plants sprung up, and formed those marsh-lands, which naturally attracted the cupidity of men of property around them ; and it became an object of great enterprize, so to shut out the water from these marshes, as to augment their produce as much as possible.

Perhaps something was gained in point of *time*, by those operations that have been there carried on---but I much suspect, that, if the ultimate value of the subject be considered, and the expence at which the alterations that have been made, is adverted to, the loss has considerably exceeded the gain. Nature in her progress, though perhaps a little too slow for the wishes of man, would have effected her purpose much more completely (and probably by this time it might have been fully effected) than ever can be achieved by the feeble operations of man. Experience has discovered, that certain places in those marshes are much deeper than others ; and, consequently, by being below the general level, are of scarcely any value; nor have they any prospect of ever becoming more valuable than they now are.---If
nature

nature had been suffered to pursue her own course, this would not have been the case. When the rising tide pushes back the muddy waters, these, when stagnant, must assume a level surface; of course, the quantity of matter deposited at the bottom, during still water, must be in proportion to the height of the water above it every where. Hence, where the height of the bottom was within three feet of the surface, if the deposition there was one inch in a given time, where the depth of water was six feet, two inches of mud would be deposited, and three inches where it was nine feet deep. In this way, it is obvious, that the hollow places must have been filled up much more quickly than the shallows. But when it is farther adverted to, that the water would have remained stagnant above the deep places many hours at each tide, while not one drop was above the higher places, it must be evident, that the deposition of mud in the hollows, must have exceeded that on the heights, in a ratio much greater than that which is above indicated. In this manner, nature had a perpetual and invariable tendency to level the surface of this
bottom,

bottom, and gradually to raise every part of it above the surface of the water nearly in an equal degree, so that every part of the field must have been, at last, nearly of the same value. Many millions of acres, the most fertile on the globe, have thus been raised out of water; and immense marshes have thus been filled up, which the weakness of man alone has prevented him from effecting.

The operations of man, have, in this instance, effectually deranged this beautiful economy of nature. Cuts have been made, through which the rivers were to be conveyed to the sea, without being suffered to spread, at any time, upon the marshes. What are the natural consequences of these operations? In the parts of those artificial channels, where the water is made to stagnate by the tide, a considerable deposition of mud is made, which tends gradually to raise the bottom of those rivers, the lowest of which were originally intended to operate, and did in fact operate, as drains to the adjoining fields, and to make it higher than these fields, and thus for a short while only answer the purpose for which they were

were originally intended. Now, although the current where the rivers are considerable, does tend to sweep away part of that mud, at the retreat of the tide, yet a great part of it remains, and this must either be scooped out, at a great expence, or the land be destroyed by hurtful water.

In the mean while, all that mud which is carried forward, past the marshes, by the rapid current of the rivers, now confined to a narrow bed, is repelled by the tide, when it gets past the mounds, and must there gradually accumulate, so as to form a bank beyond the marshes, which, in time, will rise above the surface, and, if permitted, will rise higher than the present low lands, so as to leave them like pits, that must be subjected to a perpetual and heavy charge, to render them good for any thing.

From this plain and obvious reasoning (without entering into the consideration of other particulars, which tend to the same point) the conclusion above drawn seems to be incontrovertible. From that reasoning, likewise, it follows, that the best mode of ever rendering those fields sound land, is to put them under such ma-

Q nagement

nagement as to enable the owners to suffer the waters, when in flood, and, consequently, in the muddiest state possible, to have free access to these fields when they can sustain least damage from it (especially those that are the deepest) and to allow that water to run off, after it has remained stagnant for a short while, for the purpose of depositing its mud. But as the division of property there, will render it impossible ever to get such a bold measure generally adopted, and as it would require stronger mounds, than can, in general, be erected round private property, to render this measure locally practicable, it seems to me probable, that no effectual remedy can ever be there applied for removing this evil.

In the mean while, the progress of nature may be seen going regularly forward on the banks of the Humber; the tide, in which estuary, pushes the mud that is so copiously brought down to it by the Trent, the Ouse, the Darent, and many other rivers, towards the shores every where around it, though with some diversity of progress,

progreſs, according to ſituation and circumſtances, to which it is making continual additions of land, that when it has riſen high enough, is among the moſt valuable which are to be found in the kingdom.

F I N I S.

FROM THE SEA

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DISQUISITIONS
ON THE
DIFFERENT VARIETIES
OF
WOOL-BEARING ANIMALS, &c.



ADVERTISEMENT.

THIS Essay was written for the Bath Society, and published in the Eighth Volume of their Memoirs, from whence it is reprinted, with considerable Additions.

*Disquisitions concerning the different Varieties
of WOOL - BEARING ANIMALS, and
other Particulars connected with that
Subject. Written in the Year 1794.*

IT has been hitherto, in general, believed, that the sheep is universally a wool-bearing animal, and that there is no other creature upon the globe that carries *wool*, in the strict and proper sense of the word, but sheep alone. But, there is now reason to doubt if either of these propositions be strictly true.

Among other good effects that will result from the researches of the Society instituted for the improvement of British wool, we have already become acquainted with the nature and distinguishing peculiarities of a great diversity of *varieties* of sheep, and other animals, that were not before known in Europe. It is to that source we owe an account of the different varieties or breeds of sheep, that have been discovered in the Russian dominions, by the learned

Dr. Pallas, so well known in the Republic of Letters, by his many ingenious Works in Natural History, and other branches of Science; a translation of which into English, was lately published in London. By the same means, we have become now perfectly well acquainted with the Spanish sheep, and its distinguishable peculiarities; as well as with a great many other varieties of the sheep from many parts of Asia, differing from each other in a much greater degree than ever was suspected before, in Europe, was possible.

It would take up too much of the time of the Society, were I to enumerate, in detail, the individual varieties that might be specified. I shall here only briefly state, that (in as far as I yet know) all of them may be reduced to one or other of the three following classes, or the mongrel breeds resulting from an intermixture with each other, viz.

CLASS FIRST.

WOOL-BEARING SHEEP, *properly so called.*

THIS class comprehends a great many of the varieties of sheep found in Britain,
and

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and throughout the greatest part of Europe. Sheep referrible to this class, are also found in Asiatic Russia, in Africa, at the Cape of Good-Hope, and in various parts of India.

Among most of the varieties of this class, unless where it has been purified by a careful selection, continued for many years, there is found intermixed with the wool, in different proportions, a kind of short, opaque, brittle, unelastic hair, usually of a dead white or chalky-colour, which is well known to manufacturers, and is easily distinguishable from other hair. It is known by the name of *stitchel*-hair in some places. In other places, it is called *kemps*; and, probably, it has many other local names, with which I am unacquainted. This kind of hair does not loosen from the skin at the same time with the wool, and may thus be, in some measure, separated from it among some of the purer wool-bearing breeds. I have reason to believe, though I am not absolutely certain of the fact, that this kind of hair is peculiar to the sheep of this class, and is not to be found in either of the other two classes, unless where they participate with this one in a mongrel breed.

CLASS SECOND.

HAIR-BEARING SHEEP,

Whose pile is long in the staple, and of a quality that admits of being employed in many manufactures, nearly for the same purposes as wool.

SHEEP referrible to this class, have been usually confounded with the former, inso-much that they have almost entirely escaped the notice of naturalists and others. The pure breeds of this sort are scarcely any where to be found among *manufacturing* nations; but they are reared, in preference to the wool-bearing sort, among the Russians, and other northern nations, where the skins of sheep, with the fleece on, are used for clothing, as they are found to be much more durable than those which carry wool properly so called. There are, however, a great many varieties among the breeds of sheep in this country, which are mongrels between this class and the former. Here, however, as in most cases where accurate distinctions are wanted, although it seems easy at first sight to distinguish wool from hair, by the crispiness of the former, in consequence

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sequence of which, it shrinks in length, so as to require to be stretched out before it can be accurately measured, which is not the case with hair in general, yet this is found to afford a rule too vague for accurate discrimination. The following characteristics, may, I think, be sufficiently accurate to be relied on :

1st, Wool, like the body-hair of most animals, is an annual production, springing from the skin of an animal. It consists of a great number of distinct filaments, that grow more or less close to one another in different breeds ; but which spring out of the skin about the same time, like corn from a cultivated field ; advance nearly with an equal rapidity, till they have attained their full perfection of growth ; they then loosen from the skin nearly at the same period (when a new crop springs up below) and fall off in large parcels, all at once, so as to leave the body, at one period, nearly bare, or covered only with a short coat of wool. Hairs, on the other hand, (such of them as are of an annual growth only) loosen from the skin separately, and at remote periods from each other, and, unless where they are accidentally matted together,

so as to entangle the loose hairs among those that are fast; they fall off individually one by one, and are succeeded by other individual hairs to supply their place. And as this process goes on through the greatest part of the year, the length of the coat of *hair*-bearing animals, if left to themselves, is not near so different, at different seasons of the year, as that of wool-bearing animals.

Hair, indeed, as well as wool, seems to part from the animal more freely during the spring and earlier part of the summer than in the autumn and winter season; but as the hairs loosen individually, and fall off separately, and as fresh hairs seem to spring out to supply the place of those which have fallen off the moment they are displaced, as takes place with regard to the shedding of ~~teeth~~ among young animals, it must necessarily happen, that the pile, or, as we call it, the fur of soft-haired animals, will be thinner, and consequently less abundant, in summer than in winter; a fact that has been often remarked in regard to hares, rabbits, and other fur-bearing animals, but which has not, to my knowledge, been hitherto fully adverted to. This has
been,

been, in general, attributed to the effect of heat, physically considered ; and hence it has been inferred, that all fur-bearing animals would carry a thin coat of fur in hot climates universally ; a fact that is clearly contradicted by experience. This phænomenon seems to be connected rather with the revolutions of the seasons, like the incubation of birds, and the springing up of certain plants and flowers, at particular seasons of the year. The fleece appears indeed to be very thin during the warm season, but this is not so much because there are fewer hairs in it, but because many of these hairs are then so short, as to contribute little to the weight of the pile ; whereas, in winter, these short hairs have become longer, and thus thicken the pile by growing up among the longer hairs that have adhered to the skin during the whole of the summer season. This hypothesis seems to be strongly confirmed by a fact respecting furs that has not hitherto been much adverted to, which, I have reason to believe, prevails very universally, viz. that if a lock of the hair taken from any
kind

kind of fur, be held by the points, and combed the reverse way, a much greater proportion of it would always be combed out, than ever happens with regard to any kind of *wool* if treated after the same manner. Hence, I am, at present, inclined to infer, that this great diversity in the length of the different filaments in the same pile, is a distinguishing characteristic between hair and wool, let the fineness of each be what it may. I speak at present, however, only hypothetically, for I have not had opportunities sufficient to observe these facts to enable me to speak with *certainty*.

2dly, A filament of wool has no determinate proportional thickness in its different parts, but is variable in all possible proportions. Sometimes, the root-end is thicker than the points; sometimes, and indeed for the most part, in this climate, the points are thicker than the roots; sometimes, the middle is thicker than either end; sometimes, it is quite the reverse; at some times, the variation of thickness is great, and extremely perceptible; at other times, the filament is of an equal thickness throughout

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throughout all its parts. These variations in regard to the thickness of the different parts of a filament of wool, have been proved, by experiment, to depend upon the degree of heat or cold that has acted upon the animal at the time the filament was in its state of growth ; that part of it which grew during the influence of a continuation of warm weather, being always thicker than that part of it which grew during cold weather ; the difference of size varying with the difference of temperature, in all proportions, the size of the filament continuing the same only where the animal has been kept in an equal temperature of heat during the whole period of its growth.

Hairs, on the contrary, seem to have always a determinate shape and relative proportion, under whatever circumstances they shall have been produced—one species of hairs being of one shape and proportion, and another kind of another shape. In general (and with no exception, that I know of) the body-hairs of animals are thickest at the root, and taper sensibly towards

wards the point, which is directly the reverse with all wool of grown sheep in this country*.

By

* I find reason to proceed with great caution in this Disquisition, because I have not had opportunities of observing facts with the necessary precision to enable me to deduce general conclusions with the certainty I wish to do. The observation in the text is just, as far as respects the common breeds of animals that are reared in this country; but since the above was written, I have seen reason to believe, that there is a much greater diversity in this respect, than I suspected at the time that paper was written. Before that time, I had often remarked, that the kind of hair called *kemps*, which grows among the wool of our sheep, is always thicker at the roots than at the points; from whence I naturally inferred, that all kinds of hair that grows up among wool, was always of the same sort. I now find that this is not the case; for the native sheep of Jamaica, which carry a considerable proportion of very fine wool, bear, at the same time, a kind of hair, intermixed among that wool, which is totally different from the *kemps* among our wool, in many respects; in particular, it is *invariably* much thicker at the points; that is to say, coarser, of greater diameter, taking each hair individually, than at the roots. It is also uniformly of a greater length than the wool, so as to cover that wool over the whole body, which is directly the reverse with *kemps*. Each of these hairs of the Jamaica sheep is marked from the point downwards with transverse rings, of short diameter, that
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By these two criteria, wool may be, in general, distinguished from hair, where

are alternately black and white, so as to give it very much the external appearance of badger's hair.

I find reason, also, to be satisfied, that the form and external appearance of the hairs of different animals differ greatly from each other. Among those which have fallen under my own observation, the hairs of the *musk* animal (a fine skin of which I saw in the possession of Mr. FORSYTH, at Kensington) is, perhaps, the most uncommon I have seen. These hairs are stiff, and approach, in part, to the nature of quills, though they are much softer and more flexible than those of the hedge-hog or porcupine. They draw to a narrow point, and are much thicker at the root. Each hair has the appearance of being a flaccid tube, and is a little twisted, somewhat in a spiral form, so as to have a slight appearance of a rope.

Hairs differ also from each other in respect to the manner in which they are placed into the skin. The most beautiful variety of this kind I have seen, is that of the great polar or white bear, the hairs of which are placed all over the skin in tufts, with bare places between, exactly like the bristles in a clothes-brush. These are placed in rows with the most perfect regularity, like cabbages planted with the utmost precision in a garden, so that when the skin is folded back, either across the body, or lengthwise, or diagonally, the skin is discovered clear between them, in regular rows. Other variations, I have no doubt, take place in regard this particular, that have never fallen within the sphere of my observation.

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they are entirely uncompounded, without difficulty. But as all the different varieties of sheep breed readily with each other, and produce a mongrel race, in which the discriminative qualities of the parents are blended together, it necessarily follows, that where the mongrel breed is produced between a wool and a hair-bearing race, it will afford a fleece that can neither be distinctly characterised as hair nor as wool, but will participate of the qualities of both. If this mongrel shall mix again with a wool-bearing race, the fleece of the descendant will approach nearer to wool; if with a hair-bearing race, nearer to hair; and so on, they may be blended *in infinitum*. By this means, the distinctive characteristics of hair and wool may be, in time, entirely lost, and fleeces be produced that are neither the one nor the other. This seems to be precisely the case with most of the breeds of sheep in Britain at the present day; and we must go, in some measure, out of the island, to recover the genuine breeds; but which, if attended to, will enable us to account for various phenomena that have puzzled many intelligent men.

The

The most uncontaminated breed of wool-bearing sheep I have as yet met with, is, the Shetland breed ; and there the wool rises so entirely from the skin, about the beginning of June, as to render the shearing of their sheep unnecessary. It may be plucked off at that time without occasioning to the animal the smallest uneasiness, as it will fall off of itself, if not taken away ; the young fleece springing up beneath it, like a young shorn fleece. The same phenomenon is observable in all the breeds of sheep in the northern parts of Scotland, where the proper time for shearing is always indicated by nature, and must be attended to. For although these sheep have got such an intermixture with the hair-bearing race as not to allow it to loosen quite so entirely as that of the Shetland breed ; yet it is loosened to such a degree, that if the sheep are shorn too soon, and before the wool is properly *risen*, as the phrase there is, it is difficult to pass the sheers through it, and the skin is left very bare, the young wool not being yet grown. On the other hand, if that shearing be too long delayed, the young wool has grown to such a length as to entangle

tangle the sheers in it, so as to cut off a part of it, which is both troublesome to the sheep-shearer, and when it is thus shorn, the wool is useless. But when the wool is risen to its proper state, the sheers slide over the young fleece, and cut off the few remaining hairs of the old fleece with the utmost ease, so that the sheep discovers no marks of being new shorn, and looks like a lamb in that respect.

It would seem that there is a much greater proportion of the hair-bearing race among the breeds of sheep in the southern parts of the island; for I observe that Mr. LISLE, who lived in Hampshire, and was an attentive observer, though he had heard of this young wool, under the name of *rowety*-wool, had never seen it. It is well known in Scotland, that this phenomenon does not depend on the leanness of wool-bearing sheep, as he supposes, but takes place among those that are in the best condition soonest*.

The

* I find that most people have an idea, that the phenomenon of young wool rising at the bottom of the fleece of sheep before shearing, and all the peculiarities here mentioned, are entirely occasioned by a check the sheep have received from a want of food in the winter:

The purest of the hair-bearing sheep I have seen, were some fleeces that were sent to me from the Baltic, which were as evidently hair as the fleece of a goat, though finer and softer. The Russians prefer this breed of sheep, because the fleece, when at its full length, adheres so much more firmly to the skin than wool does, that it lasts much longer when made into clothing than the other; for which reason, a wool-bearing sheep among them is a great rarity.

Among the sheep referrible to this class, there are some breeds which afford a small quantity of a very fine soft wool underneath the hair, of which the *Argali* of PALLAS

to this opinion I cannot accede, for the reason after-mentioned; though I know well that when a sheep has sustained a great stress of weather during winter, it does happen that the old fleece sometimes separates prematurely from the skin; but in that case the fleece becomes matted, and assumes an appearance extremely different from the natural healthy rising above alluded to. In this last case, the wool does not separate in the early part of the spring as where it is matted; but it adheres to it till the month of June at least, and even then it loosens in a gradual manner, as the young fleece begins to rise, and always soonest upon the sheep in the best condition; which, on that account, are often shorn ten days or a fortnight sooner than the others.

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is a noted example ; but the greatest part of the varieties we know have none of this. I have never heard of an unadulterated breed of this kind that had stichel-hair among the fleece, though it is often found among the mongrel breeds between this and the former. Neither have I ever heard of a finer kind of wool being found at the bottom of the fleece of any of the wool-bearing breeds.

The very long wool of Lincolnshire, which I have examined with care, appears to be from a mongrel race, very nearly allied to this class, with a small blend of wool in it ; and is of a harder feel than some of the pure hairy breeds, some of which are tolerably fine and soft, and very tough and durable in work, and have a fine glossy silky-like appearance. I have had wool, of the genuine wool-bearing breed of sheep, that measured $17\frac{1}{2}$ inches in length, which was extremely fine and soft, and nothing resembling that hasty kind of hair-wool in Lincolnshire.

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CLASS THIRD.

SHEEP *that carry* SHORT THICK HAIR,
which in no respect resembles wool of
any sort.

OF this variety of sheep-species we have no breeds in Britain; but that such sheep do exist, we have the clearest proofs. So little are they known, indeed, in this country, and so little is it suspected here that such an animal exists, that I was not a little surpris'd when I first saw one of this kind, and therefore examined it with a good deal of attention. This creature was on board a Danish East-India ship that put into Leith roads last season [1794] and was bought, with several others of the same sort, as they assured me, in the island of Madagascar. It was a ram of a good size, and was covered all over with a thick coat of short thick stiff hairs, like those of a horse, but rather stronger in the pile, and shorter. The colour was a fine brown, The hair lay close to the skin, and was very smooth and glossy, like the coat of a well-

dress'd horse, in fine order. They assured me, it had never had any other covering on it but what I saw, and that all his companions were of the same sort.

This fact threw the subject of sheep into a new point of view, that I had never adverted to before; and enabled me to account for some phenomena respecting sheep, that had puzzled me a good deal. In the account that Dr. PALLAS had given of the famous Boucharian lamb-skin furs, some of the peculiarities he mentioned appeared to me to be incompatible with the nature of wool, and much more nearly allied to that of hair. But, as I had no idea that any sheep of this kind existed, I was perplexed about it, and could come to no decided opinion respecting it. Since then, I have had an opportunity of seeing a night-gown, lined with Boucharian lamb-skin fur, which, I find, consists of nothing else but *hair*, without the smallest intermixture of wool. It is somewhat longer than the Madagascar sheep's hair, softer, and gently waved by means of a little curl upon it, which gives to it the beautiful foliage-like appearance for which these furs have

have been so much valued; so that this forms a second variety of this class of sheep.

While I am just writing, I have received a letter from Sir JOSEPH BANKS, bart. on this subject; who says, "I once imported three sheep from Spain, which were as sleek and smooth as a horse, and never, at any season, showed the least sign of wool or down in the most minute quantity." The fact, then, is incontestibly established, that sheep which produce as little wool as horses, do exist; and, perhaps, they are much more common than we at present suspect. The Boucharian breed of sheep is kept in immense flocks, over the extensive plains of Great Tartary. I have been also assured, of late, that they have a breed of this kind of sheep in the island of Antigua.

And last winter [1796-7] I saw a sheep of this sort, in a field near Dulwich, in Kent, within three miles of the metropolis, feeding quietly, and very tame—so as to suffer me to come quite close up to it, to examine the hair. Where it had come from, I could not learn; but, it seemed to

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be a different variety from the Madagascar sheep I had formerly seen. In colour, in particular, it was very different; the Madagascar sheep being of a clear glossy brown, this one white, with a few dark-coloured spots upon it. So that this kind of woolless sheep seems to be by no means rare. I am assured, that the greater part of the sheep in India are of this sort, though there are also many of the wool-bearing race to be found in those regions.

A natural inference from these facts is, that since we find one class of animals, some breeds of which produce wool, and other breeds produce nothing but short hair, in no respects resembling wool, may not a similar diversity take place in regard to other classes of animals? And although it should happen that the inhabitants of one country should be possessed only of the hair-bearing breed of creatures of that sort, like the Madagascarese sheep, and know nothing of any other sort; yet, there is no reason, from that circumstance, for them to conclude, that no other breed of that kind of creature exists. This train of reasoning being suggested, it roused the mind to attend

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tend to facts; and I had soon occasion to observe, that so far from having reason to be surpris'd at finding breeds of sheep so much diversified, as above set forth, there were innumerable well-known facts, which, if adverted to, would have led to the same conclusion.

For example: there is no man in Britain, who has not had occasion to observe as great a diversity in regard to the coat of dogs as of sheep.

1st, The smooth-haired dog; examples of which, are, the Italian greyhound, and Spanish pointer.

2^{dly}, The long-haired, soft, wavy-fleeced dog; as in the English spaniel, and Newfoundland dog.

3^{dly}, The wool-bearing dog, or, at least, the dog that carries a coat, which for closeness, length, and softness, may be compared to wool, is very common. Some of them carrying an immense quantity of hair, of a long lank quality, and others carrying it of a close curled texture, very like the fleece of many kinds of sheep. The fleece of these creatures must be shorn at the beginning of summer, to let them be com-

fortably cool; and I have seen it spun and worked into stockings, which could not be distinguished from wool.

I have in my possession at present, some of the hair of a dog of this kind, that I found in London, belonging to a blacksmith, which is soft as wool, and which I find has among it a few hairs resembling, *in every respect*, that kind of hair called *kemps*, which has been hitherto deemed quite peculiar to the sheep kind.

N.B. There is a kind of fox, in Siberia, that carries a fur exactly like *wool*, as I have been assured by a gentleman who lived long there. The Russian name of it, being literally translated, is, *the little dog's fur*.

The same diversity is observable in regard to goats: as,

1st, The smooth short-haired goat, very common.

2^{dly}, The long-haired shaggy goat, very common also. The hair of this kind of goat is usually very coarse; but underneath it, as in the long-haired breeds of sheep, there is a quantity of wool, of an exceedingly fine quality, which may be separated from

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from it about the month of June, by combing. From this circumstance, it would seem that this wool, like the *wool* of the sheep, rises from the skin, and becomes loosened from it, while the hair still adheres firmly to it. Of the fineness of the quality of this kind of wool, you may satisfy yourself, by examining the small shred of a little web that will accompany this, of that kind of wool, which was manufactured under my eye here last summer. There was as much of it as made three full-sized shawls and a waistcoat-piece, from whence the pattern sent was cut. The chain is silk, as there was too little materials to make it of wool. These shawls were compared with the finest India shawls that could be found in this place, and were deemed softer than any of them. The shawl-wool in India is precisely of the same nature, and is obtained from the Thibet goat. I have examined some Thibet goats in this country, and find their hair rather longer and coarser than the common European goat, from which it differs little. If it was a fair specimen I saw, the *wool* was rather less

less abundant on these than on the common goat.

3dly, The wool-bearing goat, for so I think the Angora goat may be called, whose hair is as fine, as soft, and as fit for work, as almost any wool; but whether it *rises* like wool, or is in this respect like hair, I have had no opportunity of observing. A specimen of Angora goats-hair, produced in Britain, will accompany this.

Whether there will ever be discovered the same diversity of hogs, I cannot tell; but we already are acquainted, in Europe, with something analogous to the two first-mentioned breeds of sheep, viz.

1st, The smooth short-haired Chinese breed. The Jamaica breed of hogs belongs also to this class.

2dly, The long-haired breed, having wool under its long bristles; of this kind, is the small breed of hogs found in Orkney and the Shetland Isles. Its bristles are very long and shaggy, and under them is found a very abundant quantity of wool, which is soft; but its peculiar qualities have not been as yet sufficiently investigated. I have
hitherto

hitherto heard of no breed of hogs that carries wool only.

Hence it appears, that the diversity of animals that carry *wool*, is much greater than has hitherto been in general suspected; nor can we at present say, with any degree of certainty, that there may not still exist, in some corner of the globe, one or more of every species of domestic animals we are now in the custom of rearing, and that do not carry wool with us, which may also carry wool, as well as some varieties of the sheep. And since it is well known that the inhabitants of Europe have derived great advantages from selecting the *wool*-bearing breeds of *sheep*, and rearing them in place of the smooth-haired sort; it is equally certain, that, could we discover any varieties of the other domestic animals of the smooth-haired kinds, that we have been accustomed to rear, which should afford *wool* as the sheep does, the benefit we might derive from substituting these wool-bearing breeds, instead of those hairy sorts we now propagate, would be very great, if their qualities in other respects be nearly the same.

Of

Of all the varieties of domestic animals we have been accustomed to rear in Europe, next to the sheep, the bullock is the most valuable. We, it is true, like the inhabitants of Madagascar with regard to sheep, have been hitherto in the custom of rearing the smooth-haired bullock only; and though, perhaps, like the inhabitants of Madagascar, we may have accidentally heard that there are some varieties of this class of animals that carry something like wool, in other parts of the world; yet as these have never come to our door, and presented themselves to us, we either doubt if such animals do exist, or conclude they would not thrive with us, and therefore sit still, contented with what we have, without making any efforts to better ourselves. Is it not a well known fact, that we have continued for more than a hundred years past to import wool from Spain in great quantities every year, without ever once attempting to rear the breed of sheep that produced it, though they were in a manner at our door? And is it not also known, that instead of making a fair experiment to ascertain

certain with precision whether that wool could be produced here or not, writers have been squabbling with each other about the possibility of a thing which could never be proved *pro* or *con* by reasoning, but by fair experiment only? And is it not also a fact, that although it be now proved to demonstration, by repeated experiments, that the wool of sheep brought from Spain, does not degenerate in Britain, there has been, till this hour, no attempt made to obtain a single individual of the *finest* breed of sheep from Spain? And is it not also a fact, that because those sheep that have been brought over from Spain, at random, have not been so fine in the carcase as some of the selected and improved breeds of sheep in Britain, that different persons are still disputing about the possibility of having sheep with a good carcase from Spain; as if a fact of this sort could be ascertained without accurate trial and experiment? Thus do we sit in our elbow-chairs, and argue, without data, till we reason ourselves into indolence and inattention, that make us remain contented with the dregs only of what
might

might easily be within our reach. To men in these circumstances the words of the poet may be applied:

O leaden-hearted men, to be in love with death!

It is most certain, that the person who ventures to rouse the attention of men to the investigation of facts which they have not been accustomed to take notice of, must inevitably expose himself to the sneer of ignorance; but that is of little consequence, if it should chance to throw a single ray of light upon a subject that has been hitherto involved in darkness.

That there is nearly an equal diversity of breeds of cattle as of sheep, scarcely admits of a doubt; of which the following facts are proofs:

1st, The short smooth-haired breeds. Of these, the shortest I have seen, is a bull, of the *Zebu* kind, that was lately exhibited in Edinburgh, as a show. His hair did not exceed half an inch in length, and was very close, firm, and elastic. There are many breeds of cattle in Britain, the Holderneffe in particular, the hair of which is short and very smooth.

2^{dly},

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2dly, The long soft wavy hairy breeds. Of these the Lancashire cattle are a good example; and many of the Highland breeds, some of which have manes like horses.

3dly, The long soft wool-like bearing breed, of which the buffaloe, or rather bison, of Louisiana, is the chief. The hair of this animal is said to resemble clothing wool, in length, in thickness, and in closeness; a small specimen of this wool is inclosed, which I received from Sir Joseph Banks, bart. But as the creature has never yet been domesticated, or subjected to particular observation, by men whose judgment could be relied upon, our notions of it are but very imperfect. I do not hear that there are any long hairs upon this breed of cattle.

4thly, The long-haired wool-bearing breeds. Belonging to this class there are three varieties, obscurely known, viz.

1st, The *Sarluc*, by some naturallists called the grunting ox, an animal of the Southern Tartary, which is not yet sufficiently known. The fleece of this creature

is

is said to be thick and long, falling down below its knees, and of a very fine quality.

2dly, The Chittigong cow, of the higher Hindostan, which is described nearly in the same terms.—Its hair, or wool, is much esteemed by the natives, and is applied by them to various purposes.

3dly, The Musk ox, of Hudson's-Bay. This animal is much better known to me than the former, as I had the description from a gentleman in Edinburgh who lived many years in Hudson's-Bay, and who had seen thousands of them, dead and alive. The whole body of this creature, which is rather less than a middle-sized ox with us, is covered over with a very close fleece of long, soft, flexible hair, of a fine quality, which might be employed in manufactures for many of the same purposes as wool. Beneath that hair, and towards its roots, lies another coat of exceedingly fine wool, which could be applied in fabrics of the finest quality. It has been spun and worked into gloves and stockings, which are said to be as soft as silk. The buffaloe-wool inclosed, I showed to the gentleman, who

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said

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said it was nothing like so fine as that of the musk-ox.

The flesh of this kind of ox is very fine, unless at the rutting season, when it acquires a musky flavour, from whence its name. Herds of many thousands of them are to be found up the country, among the Esquimaux, but none of them have ever yet been domesticated. They do not seem to be either so wild or so ferocious as the wild breed of European cattle that are still kept in Whittingham-park, Northumberland.

To show what practical uses may be derived from these facts, I shall beg leave to subjoin a few farther observations on subjects connected with this, that have resulted, in some measure, from the enquiries which have been set on foot by the wool society :

1st, It is now ascertained, that all the varieties of sheep yet known do readily intercopulate with each other, and that the progeny is a prolific animal, capable of continuing the species ; but that in respect to its characteristic qualities, it is of a *mongrel* race, participating nearly alike of the

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qualities of both its parents. And as these mongrel breeds may be intermixed with other varieties *in infinitum*, it may in many cases happen, that new mongrels may be produced, in which the distinguishing peculiarities of the original breeds may be blended in all possible proportions, and lost.

In like manner, the varieties of dogs may be blended and lost, if no care be taken to preserve them; and so of cattle: At least, we know for certain, that the different European breeds may be so; and we have reason to believe, that the buffaloe, the zebu, and the other varieties that have not yet been tried in Europe, may be blended together.

2dly, The effects of climate and food, in altering the qualities of the *breed*, are found to be nothing; though the effect of these things upon the individual creature that is subjected to their influence, may, in some cases, be very perceptible. For example:

It has been shown above, that the wool of *wool-bearing* sheep is affected by heat or cold; but this is nearly in the same manner as heat or cold affect the mercury
in

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in the thermometer. It is a momentary impulse, which ceases to operate the instant its influence is withdrawn; and the animal, which may have been made to undergo great variations of heat, returns to its former state as soon as its original temperature is restored. But even this variation seems to be felt only by the *wool-bearing* breeds; and is, besides, of much less powerful influence than has been usually supposed. Nor is there a single fact, that has ever been discovered, that gives the smallest countenance to the generally-received opinion, that heat tends either to make the fleece thinner in pile, or to encourage the growth of hairs among it; far less, that it operates, as M. BUFFON and his followers assert, in producing permanent changes on the descendants of the animals.

Heat likewise tends to accelerate the fattening of some animals, to whom it is congenial; as the hog, to an astonishing degree.

Richness of pasture also tends to produce temporary changes. On the wool: there is reason to believe it tends to augment its

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length

length *in some degree*, though but a little : it adds to its softness and toughness ; but, in regard to coarseness or fineness, no fact has as yet been found to ascertain that it has any sensible effect, though I am aware that *opinions* are here as decisively adopted, as if the facts had been fully ascertained. On the carcase : abundance of food is well known to augment the size of all animals to a certain degree, when compared with scanty feeding. A scarcity of food, approaching to the state of starvation, is also well known to render the wool which grows at that period of starvation, brittle and unelastic.

3^{dly}. The influence of breed, in propagating the qualities of the parent stock, or in altering the qualities of it at pleasure, by blending it with others, may be said to be all-powerful. There is not a single fact, that I have ever been able to meet with, properly ascertained, which tends to show, that the distinguishing peculiarities of any breed of animals can be sensibly changed in its essential characteristics, by any change of climate, or any other circumstance, except an intermixture of blood alone ; but innume-
rable

rable facts may be found that ascertain the contrary. The Persian and Arabian breeds of horses brought into Europe, are only changed by intercopulating with other breeds. The Chinese hogs may be continued for ages unchanged, if no cross be permitted. These facts are notorious; and every other fact upon this subject tends to establish the same conclusion.

4thly, Although the same breed of animals appears not to be liable to be changed by climate, or other extraneous causes, yet it is found by experience, that individuals may be met with, among every breed of animals, which are, in some lesser circumstances, different from others, though they still possess the general characteristics of the parent breed, arising from circumstances that have hitherto eluded our observation, and which it therefore exceeds our power either to accelerate or to retard. So strong also is the propensity of nature, in all cases, to produce its own kind, that if the individuals possessing these qualities, thus, as we would say, accidentally procured, whether beneficial or hurtful, be selected and put to breed with others that possess

qualities somewhat of the same sort, it is found, that the descendants of these selected animals will, in general, be possessed of the distinguishing peculiarity for which they were selected, in an eminent degree; though among these also some individuals will be found to have less of it than others: And if these least approved individuals be banished from the selected stock; and those, both males and females, which possess the wished-for quality in the most eminent degree, be put to breed together, the descendants of these will be still more improved: and by continuing this mode of selection for a great length of time, the improvement, as to this particular quality, may be carried to an indefinite height. In this way, may be produced an improved breed; which, though agreeing in the general characteristics with the parent stock from which it was selected, may possess some peculiar qualities in a much higher degree than it does.

It is of much importance to the practical farmer, to advert to this peculiarity in the economy of nature, because it puts it very much within his power to benefit himself,
by

by attention and care, in regard to circumstances that would otherwise seem to be entirely beyond his reach. For were he to be persuaded that certain peculiarities he wishes to obtain, are necessarily dependant upon a temperature of climate he never can enjoy, or that certain bad qualities in the animals he breeds are inseparably dependant upon the nature of his pasture, which it exceeds his power to change, he must of necessity sit down contented with what he has, without a hope of improvement; but if upon examining the facts above stated with attention, he shall find that the influence of breed is so powerful as is there stated, he will be at pains, in the first place, to look around him, to see if he can discover any breed possessing qualities, upon the whole, more valuable than his own, which is found to subsist on pastures of a quality not better than his own; and when he has once found them, continue, with uninterrupted attention, to select the best in all respects, particularly those that thrive best among them, to breed from. This has been done by Mr. BAKEWELL, and those who have adopted his system, with such success,

as not only to establish the principle for which I contend beyond a doubt, but also to give room for encouraging others to adopt a similar plan for improvements in other respects, than those that seem, hitherto, to have come within the compass of his plan.

5^{thly}, There seems to be no reason for believing that any one peculiarity we may be in quest of, is necessarily connected with, or dependant upon, any other peculiarity in the animal creation. For example: The improvers of live stock, in the present age, hold it out to view, as a general principle, that a facility in fattening is invariably connected with certain peculiarities in shape; and of course they conclude, that, wherever these peculiarities of shape are to be found, the facility of fattening will be found also, and the reverse. This, I contend, is a false principle, and I venture to say, that when the facts shall come to be thoroughly investigated, their conclusion will be found to be erroneous; indeed it is in some degree departed from in *practice* already, though in theory the principle is still adopted, without limitation. A few years ago, shortness of leg was deemed a point indispensably

dispensably necessary in a feeding beast, and it went the length of almost being deemed—the shorter the better: this is now no longer contended for. Many of the characteristics of the present day will, in like manner, gradually fall into disuse, as people come to open their eyes on this subject. The fact is, I have seen animals that had a powerful tendency to fatten, which are almost, in every respect, the reverse of the shape most highly esteemed at present, and the contrary. And by referring every person who has had opportunities of observing *many breeds* of the same kind of animals, to his own experience, I have no doubt, but he will easily recollect instances of the same kind; or, at least, if his mind be unprejudiced, that he will soon have occasion to observe it. To that experience, then, whether past or to come, I refer on this occasion.

One circumstance, however, it is necessary here to advert to, viz. that as the breeds of animals from which the selection was begun, were originally of very good kinds, and chanced at the same time to possess those shapes that are now deemed so essentially

tially requisite ; and as the improved breeds that have been selected from these are found to possess those shapes, it is by no means an unnatural conclusion to infer, that these shapes are in some degree inseparably connected with the propensity to fatten easily. Had it chanced that equal pains had been bestowed upon selecting from another good breed that was differently shaped, the prejudice would have been equally strong, in favour of that shape. But as the breeds that have been hitherto the object of selection, have got the start of all others in point of improvement, it is probable the prejudice in favour of their shape may long continue to prevail ; nor do I wish it to be understood that I have any prejudice against the shapes recommended. Far from it, for I think them very beautiful—I only wish to say, that that circumstance is not *essentially* connected with the other ; for as every error, when admitted as a truth, leads to unforeseen and often pernicious consequences, though the opinion objected to may not be of much consequence in the particular instance now under consideration, its influence

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may be very unfavourable in regard to others. Allow me to add one farther illustration on this head, before I put an end to this long paper :

If it be admitted, that a faculty of fattening easily be necessarily connected with certain peculiarities of shape, merely because it chances accidentally, as I will say, that these two peculiarities happen to be united in that breed of animals which has been brought forward to notice; we ought, by the same mode of reasoning, to infer, that that quality of fattening easily, is as necessarily connected with coarseness of wool, or lightness of fleece, or any other useless or hurtful peculiarity, if it should so happen that the favourite breed chanced to have coarse wool, or a thin fleece, &c. The consequence of this conclusion would be, that every man who wished to improve the carcase of his sheep, would turn away from every breed of sheep that carried fine wool or a close fleece, as he now does from those breeds that have long legs, or what is deemed in other respects, improper shapes; and fine-woolled sheep, carrying close fleeces, would come to be entirely neglected. But
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if, instead of this prevention, he should be convinced, that it might be very possible to find a sheep that would have a tendency to fatten kindly among those breeds that carry very fine wool and close fleeces; he would be as anxious to select from these breeds, as from others; and probably as successful too, if he had set out at the same time, with the man who began to select from the coarse breed. I am, myself, perfectly satisfied, from a variety of facts that have fallen under my own observation, which would fill a volume nearly to enumerate, that fine wool, for example, is neither necessarily connected with thinness of pile, (the Spanish sheep carry the closest pile of fleece yet known in this country) with shortness of staple (I once had a fleece of wool, that measured 17 inches and half, which was finer than the best Spanish-wool I could buy in London, and extremely soft) with tenderness of constitution, with a tendency to fatten slowly, or with any one quality that can be named, though it may be *accidentally* connected with these: And I have not a doubt, but when the eyes of mankind in general shall be opened, so as
to

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to admit of their examining the facts that fall under their notice, without prejudice, they will be able, in time, to select breeds that shall be distinguished not only for *one* valuable peculiarity, to the exclusion of all others, but even to obtain that valuable peculiarity conjoined with most, if not all the other peculiarities that can be desired. That period is, I fear, still at a great distance.

But, if these remarks shall tend in any degree to call the public attention to this subject, whether with a desire to refute or to confirm these remarks, it will equally answer the end in view, which is to remove hurtful prejudices, and to discover the truth. He who does so, is on my side, alike if he refutes by just reasoning, from well-established facts, as if he confirms these remarks.

The SECRETARY of the Bath and West of England Society, to Dr. ANDERSON.

THE Secretary of the Bath and West of England Society, begs leave, in the most respectful manner, to convey to Dr. ANDERSON, some few remarks and queries, which arose in the Committee, respecting his excellent paper on Wool-bearing Animals. In general, as might be fairly expected, this paper was much approved; but doubts arising on two or three sentences, they will be set done in order, and the Doctor will greatly oblige, by giving them a reconsideration and reply, as early as shall be convenient to him.

1st, “ And is it not also a fact, that
 “ though it be now *proved to demonstra-*
 “ *tion*, by repeated experiments, that the
 “ wool of sheep brought from Spain *does*
 “ *not degenerate in Britain**, there has
 “ been till this hour, *no attempt made to*
 “ *obtain a single individual of the finest breed*
 “ *of sheep & from Spain?*

* Query

* Query from the Committee. *On what experiment or experiments is this fact, if it be one, founded?*

§ From the same. *Has not the attempt been made by the king, and succeeded? Or, at any rate, are not the rams selected and sent to him by the Marchioness Del Campo, to be considered as the best?*

2dly, “ Nor is there a single fact, that
“ ever has been discovered, which gives
“ the smallest countenance to the gene-
“ rally received opinion, that heat tends
“ either to make the fleece thinner in
“ pile, or to encourage the growth of
“ hairs among it. Far less that it ope-
“ rates, as M. BUFFON and his followers
“ assert, in producing permanent changes
“ on the descendants of animals †.”

† Query from the Committee. *Is this a clear case? Do not our sheep sent to and kept at the West-Indies, rather prove the contrary?*

To JAMES ANDERSON, Esq. LL.D. F.R.S.

ANSWER

ANSWER to the SECRETARY.

DEAR SIR, *Saturday, Feb. 25th, 1795.*

I THANK you for your very kind letter of the 13th instant, which only came to hand on Thursday last; I embrace the first post for acknowledging that favour, and of giving answers to the queries your Committee have done me the honour to propose.

1st, A variety of experiments have been made with the Spanish breed of sheep, for three years past, by many of the members of the Society of British Wool. I have seen many specimens of the wool of both parents, and of the progeny, which have been compared together, by the members of the Committee and others; and in no instance, has it ever been observed, that the wool of the progeny, where the breed was pure, was *coarser* than the average of the parents. Of the effects of crossing, and
other

other peculiarities, affecting the wool in particular cases, I have not time to speak; I shall only observe, that, in general, the Spanish sheep that have come to Scotland have not been found to thrive, being liable to many diseases, especially the foot-rot. You are aware that bad health affects the *quality* of the wool, in a very remarkable degree, in some cases.

2dly, The king has certainly got sheep from Spain, as has the Society for British wool. But do the gentlemen of the Committee believe, that Mr. BAKEWELL, or any other eminent breeder, would have thought he could have obtained the very best kinds of British beasts, by getting the Dukes of * * * * *, or any other Dukes or Duke in the kingdom, to order her or his steward to buy the best, and send them to him? Such are not the steps required to make improvements of this kind. Do we not all know, that every person of high rank is liable to be imposed upon by their servants and dependants, in almost every thing? And what would have been the consequence, if the steward

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had

had wished to frustrate the liberal intentions of his mistress? No precautions have been adopted to guard against this. We know, that the *finest woolled* Spanish sheep have not been sent, because finer Spanish wool can be bought than any of them carried. And I have very great reason to believe, from the information of persons who have seen the flocks in Spain, that there are fine woolled sheep in Spain, much superior *in carcase* to any we have got *.

3dly, If any of the gentlemen of the Committee knows of any well-authenticated fact, which proves that the fleece degenerates, as specified, in the West-Indies, I shall be glad to be informed of it. I know of none, though I know it has been asserted ten thousand times, by persons who never had adverted to the fact; before I did advert to it, I myself believed it firmly; since I investigated the case with attention, I have

* For the precautions necessary to be observed in selecting sheep of the best sort, see Account of Russian sheep, Appendix fifth.

been obliged to abandon that opinion *.
When the gentlemen of the Committee ad-
vert

* It is very easy to account for the origin of this popular opinion. Wool is not an object of attention to any person in the West Indies; it cannot be there manufactured, and there are no uses to which they can apply it in its unmanufactured state, of course, the fleece of the sheep is entirely neglected, and in that state the wool of European sheep when carried thither will not be shorn, but will be suffered to loosen from the skin, and drop off of itself, the consequence of which will be, that if there were any kemps among the wool, which is very often the case, these hairs will remain fixed in the skin while the wool falls off; in which state the animal is perfectly bare of wool, and in its stead, the body is seen to be covered with a thin coat of long coarse straggling hairs only.—This fact being several times observed, is more than sufficient to give rise to an opinion, that all sheep which come from this country, have the wool transformed into hair, and this will naturally be ascribed to the influence of the climate, though nothing can be more certain than that the same phenomenon would take place in Britain. In fact, it does take place every year in Shetland, where the practice of sheering their sheep does not prevail. So much for the individual sheep, that have been sent out from this country.

With regard to the descendants of these sheep, as the few sheep that go from this country are suffered to run at large among the native sheep, they of course will intercopulate with them, so that the progeny will be a mon-

vert to the numberless opinions that are readily admitted, without proof, as facts respecting wool and sheep in Britain, they will not be surpris'd at this opinion respecting sheep in the West-Indies, being admitted. I have been in the custom, for many years past, of admitting no assertion, on subjects of this sort, without proofs; and in searching for proofs on this head, I have found a great number of facts, that have obliged me to abandon my former opinion. No opinion is more universal in the West-Indies, than that the sheep which are deemed the native breed of the island of Jamaica, carry *no* wool at all, but hair only. I had an opportunity, I think, of sending to you a specimen of the natural fleece of one of those sheep, which consists, for the greatest part, of wool, perhaps *finer* (un-

grel race, approaching to the nature of the native sheep.—These being once more crossed, will approach nearer to their nature, and so on, till, in a short time, they will be in no respect distinguishable from the native sheep.—Here, then, is a pure metamorphosis of the kind—but it is a change which has no dependance on climate.—The same thing must have happened, under similar circumstances, in Siberia or Lapland, just as much as in Jamaica.

doubtedly

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doubtedly softer) than the best Spanish wool.

Please to accept of these hasty notices in good part, and believe me to be, with great sincerity,

Dear Sir,

Your obliged humble servant,

JAMES ANDERSON.

Mr. Wm. Matthews.

ADDITIONS

Made to the above, in the year 1797.

SINCE the paper above was written, two valuable animals of the wool-bearing class have come to my knowledge, with which I was then entirely unacquainted—one of these is the Jamaica breed of sheep, concerning which, I have mentioned the nature of its hair at page 240, in putting this edition to the press. The sheep itself was discovered in Britain, by Sir Joseph Banks, Bart. who favoured me with the following account, in a letter, dated Nov. 1794. Sir Joseph had occasion to visit an acquaintance, immediately on that gentleman's return from Jamaica, and in walking upon the lawn, before dinner, he saw a sheep of a very unusual appearance.—He asked what sort of a sheep it was, and was told it was one of the native Jamaica sheep, which had been put on board for live stock, but having had a quick passage, its life had been saved. Sir Joseph, who had honoured me with some communications respecting wool
just

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just before that, expressed a desire to see its wool. Wool! said the gentleman, it carries no wool, but only hair.—Well, said Sir Joseph, let me see the nature of its fleece, whatever it be.—On that the gentleman called the sheep, which, being quite tame, came up to him.—He then plucked a lock between his finger and thumb from the back of the sheep, and looking at it for some time, he exclaimed, with some degree of astonishment—here is actually some wool, and until this moment I never did believe that these sheep carried the smallest portion of wool whatever, though I have seen great numbers of them daily for many years past! Sir Joseph examined it also, and sent the lock, exactly as it was pulled, knowing I should deem it a great curiosity. The lock consisted of hair of the kind above described, and of more than an equal quantity of wool of a singularly fine quality; being much finer than any Spanish wool I ever saw, and as soft as silk.—At that time it was about an inch long, and by the usual shearing time, I suppose it might have attained nearly to two inches in length;

and as the hair could be easily separated from the wool, seeing it is uniformly about half an inch longer, I have no doubt but the fleece of this animal would be of as great value as the best fleeces that have been ever reared in this island; as the wool appeared to me to be equally soft with Vigonia wool, which frequently sells here, when clean picked, at the rate of one guinea per pound,—and it has the advantage over that, in being of a pure white; so that it admits of being dyed of any colour. I consider this breed of sheep, therefore, as a very proper object for experiment.

It has been, in general, believed, that the breed of sheep just now described, which are found in Jamaica, are the very same sort with those in England, which have degenerated from their original state, in consequence of the influence of the climate, which is said to convert the English wool into hair,—and it has been often seriously affirmed to me, by respectable persons, that there could be no doubt of the fact, that English sheep are invariably transformed into that kind of animal after being a few months in Jamaica. I had been, however,

ever, assured by Dr. Wright, who was an attentive naturalist, and had lived many years in Jamaica, that they were a distinct breed.—But had I never heard any surmise of that sort, nor been able to account for the prevalence of that opinion in any way, the fact above stated puts the matter beyond a doubt.—No sheep that are reared in this island, ever carried a hair of the kind which is natural to that sheep; nor have we any wool that can admit of being compared with it, in point of fineness. We have never, in short, seen any wool of the same sort in this island; and that breed of sheep seems to be more nearly allied to the Argali of Pallas, than to any other breed of sheep hitherto described. None of the breeds of sheep reared in this island, approach to it in the smallest degree. It is curious to observe that the *hair* of this animal is much coarser, and its *wool* much finer, than can be found on any of the sheep reared in Britain; so that, by the vulgar hypothesis, it would seem that the climate produced two effects on the same animal at the same time, directly the reverse of each other!

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The other valuable wool-bearing animal of which I have received notice, is what has been conjectured by Dr. Anderson, of Madras, with much seeming probability, to have been the animal which gave rise to the famous Argonautic expedition, as the wool of it may, in the strictest propriety, be denominated the GOLDEN FLEECE. Hitherto it has been, in general, supposed that the epithet *golden* was applied to the fleece of Colchis, merely allegorically, in allusion to its value; but, from the specimen sent to me, it may be literally and truly called such; for I never saw any natural animal production, which so nearly assumed the appearance of gold as that does. A bit of the skin, about the size of the palm of the hand, with the wool adhering to it, was brought to Dr. Anderson, by a Sepoy, who had been employed in a military expedition to the northern parts of India, and all the account he could give of it was, that it was part of the pillage that had been obtained after the overthrow of one of the chiefs in those regions. A part of this Dr. Anderson sent to me, and it is now in
my

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my possession. The pile is soft and fine ; its colour is a bright yellow, of the colour of gold, and it has a gloss lustrous as silk. In length, it is about nine inches ; nor is it frizzed up, like most kinds of wool, but hangs down with a gentle wave, tending to a kind of spiral curl upon it, very much resembling the wool of the Angora goat in every respect, except the colour. It is evidently not dyed,—for not only is the bit of skin to which the wool adheres of its native colour, but there is plainly perceptible, a small variation in the tint, between the roots and the points of the wool, the roots being rather the lighter of the two, which would not have been the case, if it had been dyed. In short, the beauty of this lock is such as to have attracted, in a very high degree, the admiration of all who have seen it ;—and even in the present state of arts, a manufacturer gave it as his opinion, that it was an article of so great value ; that he would purchase it, if it could be procured, at an exceedingly high price :—but if we look backward to those distant periods when silk was not at all known in Europe, and

when the art of dying was but in its infancy, we can easily conceive, that the value of an article of this kind would be deemed inestimable.

We have to regret that so little is known of the animal which produces this fine fleece.—All that is as yet done, is, to ascertain that such an animal does actually exist; and that, of course, it is not beyond the bounds of *possibility* to discover it. In that enquiry, Dr. Anderson, at Madras, is engaged at present, and no man, from the great range of his correspondence, the universality of his acquaintance, and the respectability of his character in India, is so likely to succeed in the discovery of it as himself: Nor is any one so likely to procure the living animal, if it should be discovered. But such animals, if obtained, ought not to be delivered up as toys to princes, or their dependants, to play with.

Since the fact is now undeniably established, that there are various *breeds* of the same species of animals, which differ radically from each other, and preserve these distinct characteristics under every change of climate or management, while the
blood

blood continues uncontaminated ; and since we find that these variations respecting the fleece, or external coat of hair, are so very great as has been above made evident, we have reason to believe, that the variations which may take place between different breeds of the same species of animal, respecting their other qualities may be equally great and striking as those which regard the fleece ; it therefore behoves us to advert to all the peculiarities of every different breed or variety of animals, with much more care than we ever yet have been accustomed to do, if we wish to carry our improvements to the highest degree of possible perfection. This opens up a tract for enquiry, that is as yet entirely unexplored ; for, so long as an idea prevailed that the different varieties of the same species of animals were merely casual deviations from the same parent stock, these accidental variations must have been considered as of a nature so fleeting and perishable, as not to be worth the pain of accurate investigation.

In consequence of this mode of reasoning, the real qualities of the different
kinds

kinds of wool and hair, produced by different breeds of sheep, have scarcely been at all adverted to, because, where a variation was perceived, it was attributed to climate, food, &c.—and not to the nature of the breed.—Hence it was inferred, that under the same temperature, and with the same food long enough continued, all the varieties would be nearly the same. By a similar mode of reasoning, we have acquired the habit of thinking the other qualities of all the varieties of any one class of animals are actually the same; and that if they appear at times to differ, this is owing to the operation of accidental circumstances only: of course, we have been equally careless in observing the other qualities as that of the wool, so that many of these peculiarities have totally escaped our notice.—I shall beg leave here to give some hints respecting these, merely to forward this species of investigation:

The *size* of animals, like the qualities of the wool, have been supposed accidental —That this is not the case, admits of clear proof. None of the creatures we rear, are so much under our management, or so
 universally

universally subjected to our observation, as the dog; nor are there a greater diversity of breeds to be found in any species of creature.—In respect of size, in particular, this is very remarkable, for the smallest lap dog, when compared with the largest sized mastiff, is not, perhaps, one twentieth part of its bulk. And that this is not owing to the fullness of feeding, is very evident, seeing that these small dogs are in general much better fed, and more highly pampered than those of the largest size. Hence we are led to conclude, that there are varieties of the same species which are radically different in point of *size*, and which cannot be made to approach to each other, by any mode of management whatever, where the blood is unmixed.

The same thing is observable in other animals. The breed of cattle peculiar to the highlands of Scotland, may be made as fat as the Holdernefs breed; the Shetland breed of horses as the large black dray-horses in England, and the Chinese hog as the Berkshire pig; but no management can bring these small breeds to equal
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the others, in point of size, when equally well fed. Observe, I do not say, that full feeding will not raise the size; for it is an undoubted fact, that every animal when well fed, will rise to a larger size than where it is not well fed; but this rule applies equally to all animals, to the larger as well as the smaller, so that if equally well or ill fed, they will still preserve their distinctive size.

Different breeds of the same species vary from each other also in respect to shape. The pug-dog, the spaniel, the greyhound, the mastiff, are all distinguishable from each other in point of shape, by the slightest glance of the eye; nor can any management tend to confound them, if the breeds are preserved unadulterated. So is the Devonshire, the Lancashire, the Holderness, the Kiloe cattle; the Shetland, the Lanarkshire, the Suffolk, the Leicestershire sheep; the Swedish, the Holstein, the Spanish, the Arabian horses; each of which can be recognised by a glance of the eye, when compared with the others; and they are all equally permanent.

Different

Different breeds vary from each other also, to an astonishing degree, in respect to their propensity to increase in corpulency by abundant feeding. No art can ever bring the grey-hound to be as full of flesh as a breed of lap-dogs (I believe they are called shock-dogs) which have a propensity to fatten more than any others ;—and, it is not a little remarkable, that some of the leanest kind of dogs, eat the most food of any, in proportion to their size. It has been often remarked, that a grey-hound is the most voracious of all dogs, and that a mastiff, in proportion to its size, eats very little, though it may very easily be fattened. The blood-horse and the alderney-cow, can never be made so fat as many other varieties of their species.

These observations lead to very important conclusions, to the farmer ; for if such remarkable diversities be occasioned merely by the *breed*, it behoves him to be exceedingly attentive to this article, and to investigate, with the most careful impartiality, the peculiarities which essentially discriminate one breed from another ; to

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consider

consider each peculiarity of every breed, individually and separately, and not to blend them in the gross, as has hitherto been done. It would lead me much farther than I at present choose to go, were I to enter minutely into this subject—my object is not at present to teach others, but merely to put them into a train of instructing themselves; and, with that view, I shall merely glance at a few other circumstances, before I put an end to this Essay.

It is not the abundance of food, that will produce a large breed of animals in any place, though the want of food will every where stint them in size. Hence we are not to conclude, that wherever a small breed of any domestic animal prevails, it must be a poor barren country.—If the animals be fat, it is a proof they have abundance of food, whatever be their size—though if they be thin, it is not a proof that they are in want of food. The Shetland poney is of a size as small as that of the island of Tiree; but the first is a plump strong-made animal, that is almost continually fat, the last is a thin
puny

puny creature, that looks always starved, though its native food is richer. In like manner, the Alderney-cow is a hard-boned, hungry, starved-like creature, when even on the best of grafs. The Kiloe is not much higher in stature, but it is a burly looking creature, compared with the other, and has a tendency to fatten kindly wherever it has food enough. The first is a native of a fine climate and good foil; the last is found in an ungenial region, and very unfertile country.

From these confiderations, it will appear, that feveral of the questions which have been keenly agitated among warm disputants, for many years past, do not admit of a solution in the way they have contended for. One party, for example, maintains that it is more advantageous to rear large than small beafts; and, in confirmation, he produces a fact, by which it appears, that in that particular case, the large beafts were, in truth, the most profitable of the two. Another, on the contrary, maintains, that small beafts are universally more profitable than large, and states a fact, which proves clearly, that

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the small breed was indeed more beneficial than the large. They may be both right as to the particular facts alleged, and both wrong as to the general conclusion. It is not the size, but the other peculiarities of the individual breeds that influence this question; seeing two breeds, of equal size, may possess properties extremely dissimilar. It is, therefore, a groundless prejudice, either to approve or to condemn a particular breed, from adverting to its size only; of course, we ought to reject none from the particular investigation of its qualities, above recommended. For this reason, the Musk ox, of Hudson's Bay, which is rather small; the Bison of Louisiana, which is of a larger size, and strong, both of which fatten kindly; the Alderney-cow, which is also small, but valuable on account of its milk; and the Arnee, of Hindostan, which is by far the largest of the cattle-tribe yet known, should each of them have their respective peculiarities distinctly ascertained.

Of all the animals of the *Bos* tribe, the Arnee is, doubtless, the largest yet known;

known; and although largeness of size be not in itself a quality that ought to recommend an animal to favour; especially where it is to be suffered to graze upon the meadows, where the exorbitant weight of the creature may be sometimes hurtful; yet, there may arise occasions, in which great bodily strength may be of singular utility: and as it is possible to feed beasts always in the house, should the animal be in other respects desirable, the damage that might be done by its weight in pasturing, may be thus entirely avoided. This creature, when tamed, is gentle, and very susceptible of being trained to any purpose that may be wanted; but, with its other qualities, we are very little acquainted. It is known in the higher parts of India, where it is used as a beast of parade, nearly in the same manner as the Elephant, to which, in point of size, it more nearly approaches, than, perhaps, any other animal, that is yet known to us, as I chanced accidentally, to gather from the following incident:

Mr. William Haig, while first lieutenant on board the Hawkesbery East In-

diaman, then in the river of Ganges, about fifty miles below Calcutta, observed an animal in the river, alive, but floating towards the sea, carried down by the current; a boat was immediately put off, and the creature secured by means of a rope thrown over its horns, and towed towards the ship. They were surprized at the largeness of the size of the animal; and being just come into the river, from Europe, it was accounted a glorious prize, and instantly slaughtered, for the sake of fresh provisions. It was found to be a bullock of only two years old, yet when cut up, the four quarters weighed full 1450 pounds. From this datum we cannot suppose, that a beast of this kind, of full stature, and completely fatted, would weigh less than 4500 pounds; for we know that a lean bullock, of two years old, will not amount to one-third part of the weight that the same animal would have attained at nine years of age, when fully fatted; and as this creature must, in all probability, have been carried down the river for, perhaps, a thousand miles, before it was caught (none of these cattle, that

I have

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I have heard of, being bred lower than Plassy) we must suppose that it would be very much emaciated; yet all on board the ship thought it excellent eating. As the head, feet, skin, entrails, and tallow, of a fatted animal, weigh very little less than the four quarters, we shall see reason to believe that some of these, when alive, may be found, which will not be less than from 80 to 90 cwt. upwards of four ton weight! so that it must be a very stately creature. They are said to be sometimes eleven or twelve feet in height.

The horns of this breed of cattle grow right upwards, nearly in the same plane with the face. At first they spread outward, but as the creature grows older, they gradually bend inward, till at last they form nearly a circle, of a large size. I saw an Indian painting, in the possession of Gilbert Innes, esq. of Stow, in Edinburgh, representing a fight between an elephant and two tigers; a kind of entertainment, sometimes given by the grantees of India, for the amusement of the public. In this painting many people were present; some elephants were there also, under the care of attendants, and

three of these cattle were there seen also standing quietly, under the charge of their keepers, who were mounted upon them, nearly as the cornac is upon an elephant; nor were they represented as much, if at all, inferior in size to that monstrous animal.—The colour was uniformly black, except a tuft of red, or rather flame-coloured hair, pretty long, on the top of the forehead, exactly between the horns. It was guided by a rein fastened to the gristle between the nostrils. It is therefore plainly a domesticated animal, and its appearance is of the most gentle and inoffensive kind.

The Bison, or, as it is commonly called, the Buffaloe of Louisiana, is also a beast of a large size, and great bodily strength, and has a propensity to fatten kindly. It was not known that it could be very easily domesticated till of late; but I find, among other peculiarities respecting this creature, mentioned in the Seventh Volume of the Bath Society papers, written by a Mr. Turnbull, a very singular and easy method of catching them, which appears to be well known to the inhabitants of the back settlements

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tlements in America, who often go out to hunt the Buffaloe. He states, that if a female who has a sucking calf at her foot, chances to be killed, the calf never leaves its dam, even when the hunter comes up, but stands quietly by, and follows the body of its mother wherever it is carried, were it even into the heart of a city ; and as the calf is easily tamed when once got into hand, it seems to be often reared, in the back settlements, as a domestic animal. The writer of that paper does not there specify any of its other qualities, but its strength alone, which, he says, is much greater than that of the European ox, and its step longer, on which account he strongly recommends it as a beast of draught.

The *Zebu* breed of cattle has been also imported into this country, I find, from India, by several gentlemen, and is found to thrive here, and to breed perfectly well, so that it is probable, its qualities will come in time to be accurately ascertained. In regard to one particular, both these breeds possess a peculiarity, that is well known to be totally distinct from any of the breeds of cattle that are natives of this country. The
peculiarity

peculiarity which distinguishes the *Bison* from other varieties of the *Bos* tribe, is a large hump upon the shoulder, which when cut up, is found to afford a flesh that is of a quality totally distinct from that of any other part of the body, and is universally esteemed much more delicate eating. The *Zebu* is also distinguished from other creatures of the same genus, by a particular kind of excrescence, that rises from the shoulder also, but in a manner totally different from that of the *Bison*; and the quality of the flesh of this excrescence (which is of a considerable size) is different from any meat furnished by our cattle, and differs also from that of the *Bison*. This is deemed such a peculiar delicacy, that I have often heard gentlemen who have been used to it in India, say, they found all the meat in this country, harsh to their palate, so that they could with difficulty bring themselves to eat of it. It is not impossible but the meat in the other parts of the body may also differ considerably from our's, and from each other. The skin also of these animals may be found, upon trial, to be possessed of properties that may render it highly valuable

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uable in manufactures ; particularly that of the *Arnee*, which is probably, in many respects, different from that of the smaller animals of the same genus. It is certain, that the Indians make of the skin of the Bison, manufactured in their manner, a kind of leather, that is soft, tough, and very light, of which they form a kind of jerkin, or a shield, perfectly capable of resisting the force of an arrow. Whether this quality depends upon the nature of the skin, or on the mode of manufacturing it, remains to be ascertained.

I shall just add one other hint respecting *varieties* of animals of the same species, with a view to lead to an investigation, that never has yet, that I know of, been the subject of elucidation. We have seen above, that different *varieties* of the same species possess certain permanent and distinct peculiarities, that cannot be altered but by an intermixture of blood. Those peculiarities that I have taken notice of above, respect chiefly external circumstances, which are very obvious to the senses — There are other peculiarities, however, of a more obscure nature, if I may be allowed
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to adopt that expression, which, though equally useful, are not so easily ascertained by sensible marks which admit of accurate comparative trial, but which are still easily recognised, when you take two breeds that differ very much from each other.—Of this nature, is what is called hardiness, or persevering firmness under fatigue, often called *spirit*—as contrasted to that sluggish want of mental and muscular exertion, which is called *softness* in horses; the blood-horse, for example, and some other noted breeds of active horses, compared with the large black dray-horse. Of a nature equally obscure, though, I am satisfied too, equally distinct from each other, is the taste and flavour of the flesh of different breeds of the same kind of animal, though this circumstance does not seem as yet ever to have attracted the public attention in the smallest degree. Every person knows, however, that there is an exceedingly great difference between the delicacy of the meat he eats at different times; but as it is well known that the flavour of meat may be affected by circumstances that are totally unconnected with the breed, such as, in
some

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some kind of animals, the age at which they have been killed, or the nature of the food upon which they have been fed, or the time the meat has been kept after it has been slaughtered ; and as no pains is, in general, taken to discriminate how far either of these circumstances have tended to operate in the particular case in question, each individual feels himself, in general, disposed hastily to conclude, that the particular circumstance which he chances to have fixed upon as obnoxious, or the reverse, has occasioned the good or the bad flavour he perceives. Is his mutton peculiarly delicate—one man immediately concludes, it must have been fed upon heath, which gives it the high flavour.—If bad, it has been fed upon turnips ; or it is, perhaps, the age—or the size—or any other circumstance that may chance to operate upon his imagination at the time—but he seldom thinks of ascertaining with the necessary degree of precision, whether this be the fact or not. I myself know, for a certainty, that I have heard things of this nature repeatedly mentioned as facts that were incontestible, which I knew at the time to be totally different

ferent from what was asserted, when it would have been very idle, or very rude in me to have contested it: neither have I myself had opportunities of ascertaining the fact referrible to this head with the necessary precision to be able to lay down any rules that can be relied upon. My observations go no farther than to furnish me with reasons for doubting; but they have been long enough continued to authorize me to suggest hints for farther investigation. In short, I have seen reason to be satisfied that, independant of age, and food, and every other circumstance which tends to affect the taste of meat, there is a flavour peculiar to the meat of every distinct breed of domestic animals that are reared in this island, which can only be changed by blood. I do not say that this flavour cannot be altered by the circumstances above stated;—far from it—for I know that the alteration that may be produced by these means is always very great. What I mean is simply this; that under the same circumstances respecting age, food, and every other particular, the flavour of the meat of two distinct breeds will be different, in most cases.

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In regard to mutton, I shall beg leave to specify the true Welsh breed, and the new Leicestershire, as the greatest contrast to each other that I know.—The first I conceive to be by much the finest flavoured mutton I have seen, and the last the lowest.—The difference is to me nearly as great as between a golden pippin, and an ordinary apple. Whether this difference of flavour depends upon the breed or the feed, may be ascertained by very easy experiment. Let any gentleman who has a convenient inclosure, buy a score of lambs of one year old, of each kind; let them be turned together into as rich a pasture as you please, and let the two best of each kind be always chosen at the same time, when wanted, and then slaughtered, and treated in every respect alike, till the whole shall be consumed, as they advance in years. Two of the same age will thus always be compared together; if no difference in the flavour be then perceived, I am clearly in a mistake.—Many other good consequences, besides that here stated, would result from this experiment, if conducted with

with accuracy, and faithfully recorded ; and it would cost nothing.

I shall just add, that I have reason to suspect that the delicacy of flavour is by no means necessarily connected with the *size* of the breed ; for though, in this instance, it should be found that the smallest is preferable, I have no doubt but that in other trials it would be found that the reverse would be the case.



FINIS.

